THE EFFECT OF CULTURAL TREATMENTS ON THE GROWTH AND YIELD OF THE POTATO CROP

by

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C O N T E N T S

PART I

PART II

PART I

INTRODUCTION

Inter-row cultivation is a well established agricultural practice and there is general agreement between scientists and practitioners about its importance in crop production. There is no such agreement as to specific reasons why cultivation increases the crop production. Farmers believe that the increase in yield is due primarily to the effect of the treatment on soil structure making it more porous as it breaks up crusts on land into dust mulch.

Soil mulch conserves moisture and helps to increase the soil fertility. Hence, the general belief that the more the land can be cultivated the better the root crop yield will be. Experimental evidence does not support this view, suggesting rather that cultivation acts indirectly through checking weeds.

Competition between weeds and crops may be considered the most important factor that affects production. The total output of the land suffers from weed competition alone more than from diseases and insects. This was clearly shown by the annual loss estimation in the United States of America which amounted to three billion dollars annually.(57) The estimate of the annual losses from agricultural pests are as follows:

I.	Diseases of livestock (not including death from eating poisonous plants)	$ 250,000,000
II.	Plant diseases (10 leading crops + forest trees)	1,190,000,000
III.	Insect pests of plants and animals	1,125,000,000
IV.	Weeds	3,000,000,000

In Great Britain about 16.5 million sterling per annum were lost by farmers before the first great world war 1914-1918. (Long 1934 (25) This figure is undoubtedly much higher today owing to increased cost of labour, seeds, etc.

The nuisance of weeds is well expressed by Shakespeare's words:

> "I will go root away
> The noisome weeds, that without profit suck
> The soil's fertility from wholesome flowers."
>
> - Richard II, Act III, Scene iv.

Different methods and treatments are used for controlling weeds. The use of chemicals, inter-row tillage and proper rotation are just a few to be named here.

Inter-row tillage has two effects: (1) it kills weeds growing between the rows, and (2) it results in dust mulch. Dust mulch was formerly believed to help in conserving soil moisture, in fact it is still considered to do so by many farmers, although field experiments failed to show that dust mulch normally has this effect. (Pereira 1941) (35) Nevertheless, the British farmers argue that their soil and climate are different from those under which those experiments were carried out; and they maintain their belief.

Experiments show that the importance of the inter-row tillage appears to be due to the destructive effect it has on weeds rather than to the changes it brings in the structure of the soil.

Weeds compete with the crops and have a markedly depressing effect on yield of crop plants. There is

some difference of opinion among experimenters as to the factors producing this effect. Weeds affect crop plant by 1. taking up soil moisture, 2. taking up mineral nutrients, 3. making the soil toxic, and 4. by shading - thus restricting the synthesis of carbohydrates.

Of course, competition only begins when one of the essential requirements for the growth fails to offer enough supply to both weeds and crops.

The relative increase in the cost of labour as compared with the produce of the farm makes the old elaborate cultivation no longer economic. Economic conditions have forced farmers to reduce cost of production; by reducing the amount of useless cultivation we reduce cost, save time and eliminate useless labour.

It is interesting to study the interaction of cultural treatments with the root development, growth and yield of potato crop under Scottish conditions in order to give the Scottish farmers the evidence of the actual effect of inter-row tillage under their conditions.

This problem is to be attacked from the practical and the theoretical viewpoints. From the practical viewpoint the effect of cultural treatments on yield should be determined. The theoretical viewpoint is to determine the reasons of increasing yield by cultural treatments.

In the present work, attention has been confined to the interaction of cultural treatments with the

Differences in plant behaviour are shown directly or indirectly through roots. Apparently there is not sufficient knowledge as to the response of potato plant roots to cultural treatments.

The study herein reported includes:

1. The effect of cultural treatments on yield.
2. The response of roots to cultural treatments.
3. The response of foliage to cultural treatments.

REVIEW OF LITERATURE

Relation of Cultivation to Yield

Agricultural Experimental Stations in U.S.A. published a formidable volume of literature on the subject of tillage during the last half century. Much of the early work suffered little or no replication and duration. A review of the recent work is written here to show the trend of the results obtained. A complete account of the literature was not made as literature is so extensive.

In 1921, the U.S. Department of Agriculture (58) summed up the effect of tillage under the following headings: 1. prevention of weed growth, 2. moisture conservation, 3. soil acration, 4. increase of the available supply of plant food, 5. stimulation of root growth

Thompson in 1927 (45), studying the effect of inter-row tillage for six years on six vegetable crops (beets, carrots, onions, cabbage, celery and tomatoes) on gravelly sandy loam soil, concluded that weed control was of much greater importance than the

In 1938 leading members of the U.S.A. Department of Agriculture summed up the experience of the department in the following generalisation: "Tillage of growing crops is now regarded primarily as a means of weed control, as it is becoming better recognised that the chief purpose of cultivation is to destroy weeds, not to create a mulch." (59)

From the experiment, on inter-row tillage of various vegetables including potatoes, on well drained heavy silt loam, Merkle and Irvin (28) concluded that when weeds are kept under control, further cultivation of potatoes for other purposes is not essential.

Lombard 1936 (24), Russell 1949 (39) stated that the supreme function of inter-row tillage is to kill weeds.

Moore 1937 (30), reporting the results of soil and plant response to certain methods of potato cultivation on silty clay loam soil, concluded that there is no advantage in cultivation of potatoes except for weed control.

Experiments with maize in U.S.A. showed that destruction of weeds was the major benefit of inter-row cultivation. Call and /Sewell 1917 (8); Devol 1886, 1887 (11,12); Wimer and Harland 1925 (53); Weideman 1947 (51).

Result of the effect of cultivation of cotton indicates that the soil mulch had no appreciable effect on yield on a silt loam soil. (Moore and Robert 1923) (29)

Chemical weed control benefits the crop as much as hoeing; this provides good evidence that the importance of hoeing is due to the weeds it kills,

Russell and Keen 1938 (41), describing the effect of inter-row tillage on sugar beet in heavy and sandy soil and on kale in heavy soil under British conditions, showed that the results were similar to those obtained in America, but exploded the farmers' deep-rooted belief in the values of dust mulch resulting from the soil while crops were growing.

Periera 1941 (35) published results of three years' 1937-1939 work under British conditions on a sandy loam soil, showing that the frequency of the inter-row cultivation benefited the crop only by destroying weeds and not be maintaining a loose tilth. The data showed conclusively that there is no significant response to inter-row tillage. Periera 1941 (36), on a review of a crop response to inter-row tillage, has shown that tillage should be as shallow and as frequent as is consistent with the thorough destruction of weeds.

Russell 1949 (39) on the relation between cultivation and crop yield under Rothamsted conditions, concluded that the value of hoeing is to kill weeds and not to make surface mulch.

Russell 1949 (40) published data of the effect of additional inter-row tillage on the yield of potatoes. The data were as follows:

Total Produce in Tons per acre

	2 cultiv. between rows	5 cultiv.	Reduction due to additional cultivation
1942	15.66	14.9	.76
1943	8.38	8.14	.24

The data show conclusively that additional

cultivation is slightly harmful. Here more experiments should be made over a number of seasons before a final conclussion can be drawn.

Keen 1938 (21) stated that intensive cultivation of root crops results in depressing the yield.

Russell and Keen 1938 (41) stated that extra cultivation results in decreasing yield as it causes damage to the surface-feeding roots and to the leaves.

Relation of Cultivation to Root Distribution

Differences in potato plant behaviour are manifested directly or indirectly through the roots. As far as the author is aware, there are, in the sphere of Scottish agriculture, no studies on the development of the potato root under different methods of cultivation.

Investigators in America, Europe and Russia studied the root system of the potato crop. The following is a summary of the result of the work:

Investigator	Location	Date	Vert. ins.	Lat. ins.	Remarks
Ten Eycke (45)	Nth. Dakota	1899-1900	18	24	Rows 18" apart
Schulze (43)	Germany	1906	97		
Rotmistrov (37)	Russia	1907-09	24	40	
Weaver (49)	Kansas, Colorado		46	26	
Moore (30)	Ithaca, N.Y.		9	10	27 days after planting
			20	24	75 " "

Artschwager (1) stated that potato roots reach a depth of 3 or 4 feet, and often extend horizontally 2 feet from the plant. Ten Eycke found that at the end of 43 days the root of the plant in adjacent hills had met. Hutcheson and Wolfe 1948 (20) concluded that

the main growth of root was within 8 inches of the surface.

The differences in the above results may be due to one or more of the following factors:

(i) variety grown
(ii) technique adopted in excavation of roots
(iii) variation in environmental conditions both edaphic and climatic.

Sturtevant 1882 (44) found that certain systems of cultivation which interferes with the root system are a disadvantage.

Moore 1937 (30) concluded that cultivation destroys some roots between the rows, roots which in scraped plots filled the entire surface of the soil whether level or ridged. He found also that roots of unpruned plants penetrated deeper than those of pruned ones. Cultivation limits the roots in the soil surface to that area below the deepest cultivation tooth.

Russell 1917 (38) from his experience of the English heavy soil stated that only the upper 6 or 8 inches of the soil is suited to plant life, while the subsoil plays an indirect part in nutrition. This is in contrast with the results of Doneen and McGillivry 1946 experiments (13) which presented evidence that deep rooted plants, such as tomatoes and pumpkins, absorb water from a depth of 3 or 6 feet or more.

Pavlychenko and Harrington 1934 (33) studied the competitive efficiency of weeds and cereal crops under dry farming conditions. They concluded that there is competition between overlapping root system

before the tops begin to shade one another as they grow very closely. Investigations showed that weeds reduce the size of the root system. Pavlychenko and Harrington (34); Weaver and Kramer 1932 (50); Yocum 1937 (55); Coile 1940 (10) Shading usually reduces the size of the root system and the ratio of roots to shoots Biswell 1935 (5), Mitchell 1936 (27), Coile 1940 (10).

Inter-row cultivation suppresses the weed growth; on the other hand it destroys the surface-feeding roots of the shallow-rooted crops, such as potatoes, sugar beet, corn.

If the desirable effect of inter-row tillage lies in its destroying weeds and its harm in the injury it might cause to the surface-feeding roots, then it should be adjusted in such a way as to bring about as little injury to the roots as would permit the destruction of weeds.

It is commonly believed among farmers that pruning of roots results in deeper penetration of the remaining unpruned roots. Moreover, it is believed that, by deep cultivation, the soil surface is kept unfavorable for growth of roots and roots grow below the region of disturbed soil. This belief is based upon the argument that, when roots are allowed to grow too near the surface, they will later be the victims of a period of drought and low rainfall. It is argued then that these roots should be induced to go deeper and reach a low water table. Besides encouraging unpruned roots to go deep, the new branches which arise as a result of pruning will go deeper still in search of water.

Effect of Depth of Planting on Yield and Plant Emergence.

Experiments on the effect of depth of planting on yield of potatoes at Shafter on a light sandy loam soil and at Davis on heavy silt loam, showed that planting at a depth of four and six inches produced a higher yield than at nine inches.(Lorenz 1945 (26) Hardenburg (18) has reviewed a number of experiments relative to the proper depth of planting to secure the highest yield. He concluded that under ordinary conditions the four inches depth usually gives higher yield than shallower or deeper planting.

Hardenburg 1935 (17) compared two, four and six inches depth of planting in a rather heavy silt loam on rural and green mountain variety. The average number of stems per plant was significantly higher for the two inches than for the four inches depth.

Zavitz 1916 (56) found that tubers tend to develop at depth of three-four inches from the soil surface.

Hardenburg 1949 (18) stated that shallow planted tubers emerge quicker than deep planted tubers. Moore 1937 (30) stated that deep planting hastened emergence more rapidly two to three days over shallow planting and the final yield appear to be about the same.

I N V E S T I G A T I O N

Descriptions of the Experiments 1951

A comprehensive set of experiments was conducted in Steading Field East at Dryden Mains Farm, ten miles from Edinburgh.

The soil of the experiment was chocolate in appearance. The surface soil was predominantly gravelly, sandy loam with a penetrable yellowish subsoil. The soil pH ranged from 6.2 - 5.5. The field was of medium fertility. The previous crop was wheat. The field was dunged in at 15 tons per acre in the winter.

The area was cultivated on 9th May, 1951, and then harrowed on 10th May, 1951, and ridges were drawn at 27" with a 3-row potato ridge driven by tractor. Main crop fertilizer 8 cwt. per 1 acre was applied on 11th May, 1951, and ridges were split on the same day. The land was then laid out into plots to accommodate one main experiment and subsidiary small-scale experiments for taking some special observations.

Planting was on 12th May. The variety planted was Kerr's Pink.

Experimental Treatments:

1st Cultivation	13th June, 1951.
1st Hand-Weeding	15th " "
2nd Cultivation	3rd July, "
2nd Hand-Weeding	5th " "
3rd Cultivation	22nd " "
Ridging	23rd " "
Lifting	20th October, 1951.

THE MAIN EXPERIMENT

Treatment and Lay-Out: The main experiment contains the combinations of the following factors:

(a) Method of cultivation:

C_0 No cultivation.

C_1 Inter-row cultivation with tines 8" from plants (narrow inter-row cultivation W_2). Treatments carried out two times (I_1).

C_2 Same as C_1 but treatments carried out threetimes.

C_3 Inter-row cultivation with tines 6" from the plant treatments carried out two times.

C_4 Same as C_3. Treatments carried out three times. When tines are 6" from the plant inter-row cultivation is considered as wide (W_1). When tines are 8" from the plant inter-row cultivation is considered as narrow (W_2).

There are two intensities of inter-row cultivation two times (I_1) and three times (I_2)

(b) Depth of planting:

d_1 planting was 2" from the top of the ridge

d_2 " " 5" " " " " " "

(c) Weeds between plants were allowed to grow or eliminated by hand pulling.

The Layout (Plate I)

The main experiment is of split plot in randomised block system. This procedure is of practical utility in this study as cultivation treatments necessitate long plots. Methods of cultivation and depth of planting combinations put on the whole plots; every plot is split into two equal parts, one for hand weeding (h_1) between plants, and the other for no hand weeding (h_0). The whole plots were arranged in randomised block, and the treatments of the sub-plots (hand weeding) were ordinarily arranged at random within each whole plot.

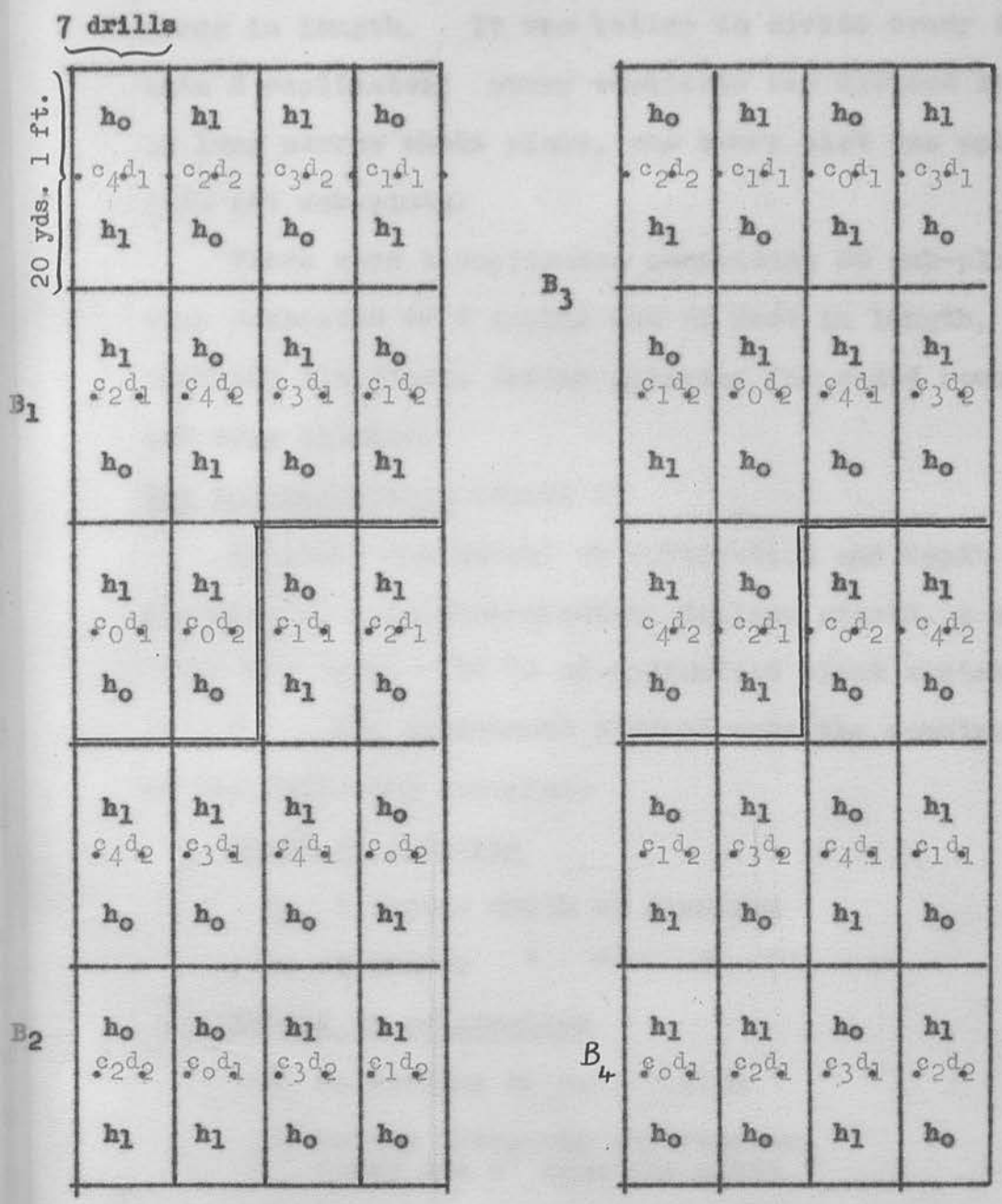
Land available for the experiment

There were two pieces of land available for the

Plate I

MAIN EXPERIMENT

Split Plot in Randomised Block System



Method of Cultivation

B stands for Replicate

c_0 no cultivation

c_1 inter-row cultivation with tines 8" from plants. Treatments carried out two times.

c_2 Same as c_1 but treatments carried out three times.

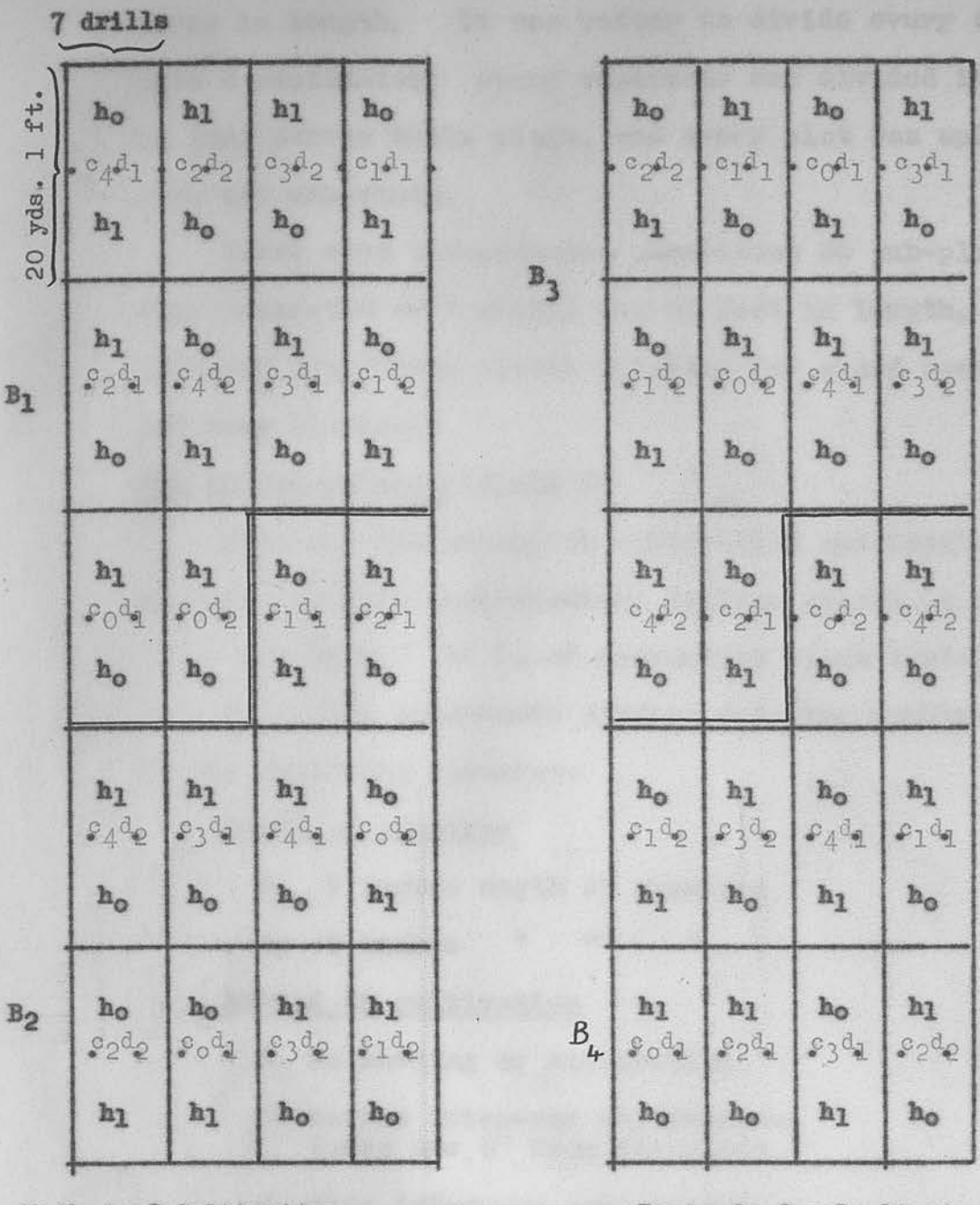
c_3 Inter-row cultivation with tines 6" from the plant. Treatments carried out two times.

c_4 Same as c_3. Treatment carried out three times.

Plate I

MAIN EXPERIMENT

Split Plot in Randomised Block System



Method of Cultivation B stands for Replicate

c_o no cultivation

c_1 inter-row cultivation with tines 8" from plants. Treatments carried out two times.

c_2 Same as c_1 but treatments carried out three times.

c_3 Inter-row cultivation with tines 6" from the plant. Treatments carried out two times.

c_4 Same as c_3. Treatment carried out three times.

Depth of Planting

d_1 planting was 2" from the top of the ridge

d_2 " " 5" " " "

Elimination of Weeds on Ridges and Between Plants

h_o weeds were not hand-pulled on ridges between plants

h_1 weeds were hand-pulled on ridges between plants.

experiment; they were separated from each other by a barley experiment. They were 35 yards apart. Every strip is rectangular, 23 yards wide and 110 yards in length. It was better to divide every strip into 2 replicates; every replicate was divided into 10 long narrow whole plots, and every plot was split into two sub-plots.

There were 4 replicates comprising 80 sub-plots, each consisted of 7 drills and 31 feet in length, and included 110 plants (after allowing for guard rows and edge plants).

The Sub-Experiment (Plate 2)

To study the effect of cultivation and depth of planting on root distribution, foliage growth, a sub-experiment was made. It is of randomised block system (4 x 2) The treatments studied were the combinations of the following factors:-

Depth of planting

d_1 2 inches depth of planting

d_2 5 inches " " "

Method of cultivation

C_0 no weeding or cultivation

C_1 narrow inter-row cultivation; tines are 8" from the plant.

C_2 wide inter-row cultivation; tines are 6" from the plant.

H hand weeding.

There were two replicates; these were 16 plots in all, each plot is 5 drills, 27 inches apart and 30 feet in length.

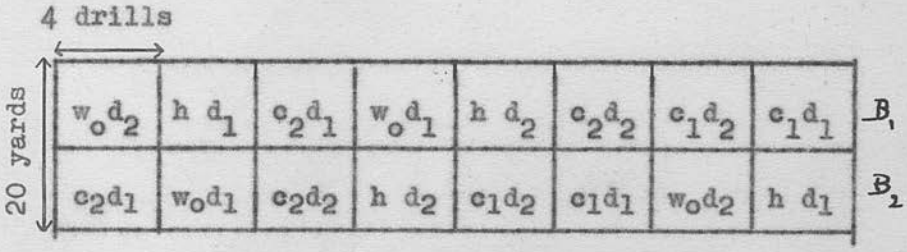
Spacing To ensure accuracy of number of plants and distance between plants, a rope of 50' long and

Plate II

THE SUB-EXPERIMENT
(4 x 2)

Randomised Block System

LAY OUT



Method of Cultivation - M

w_o No weeding

h Hand-weeding

c_1 Width of inter-row tillage, 8" from the plant

c_2 " " " 6" " "

Depth of Planting - D

d_1 2 inches depth

d_2 5 inches depth

B replicate

marked at the specific distance of 14" by tying coloured twine.

Planting Land ridged, fertilizer applied, then ridges were split. To ensure depth of planting dibbling was used.

Plant Growth Studies

From experimental viewpoint it was not sufficient to make different treatments and to get the final yield. It was necessary to interpret these results. Theoretically, to find out why one experimental treatment was better than another, was to study how the plant reacted to these different treatments at its different developmental stages. As the experimental treatments in this experiment may affect root growth, the root as well as the foliage was kept under observation.

The object of this part was to measure the reaction of the plant to the experimental treatments through observing these attributes which give information directly on the progress of the important physiological progress and which are in direct line of the yield.

Data collected on main experiment

The following records were obtained from the main experiment.

1. The counts of the coming-up of plants above ground at two-day intervals from 12th June, 1951, were taken on every plot of the experiment.

2. The number of leaves of plants per sub-plot was taken on 26th July, 13th August and 23rd August, 1951.

3. The number of weeds per square metre was recorded for every sub-plot from one replicate, four samples per sub-plot, on 2nd July, 8th, 19th and 24th July.

4./ The Total yield, and the yield of the commercial grades, viz. ware (over 2½" meshed riddel) seed (2½ - 1¼") and chats (through 1¼" riddle) were recorded for every sub-plot separately.

Data collected from the sub-experiment

The following records were obtained from the sub-experiment:

1. The dry weight of plant parts, stems, leaves, tubers for three plants per plot from every plot of the experiment was estimated on 27th June, 12th July, 2nd, 14th August, 6th September.

2. The dry weight of tubers.

3. The lateral extent of the root system for three plants from every plot of one replicate.

4. The maximum depth of the root system of plants under lateral extent observation was recorded.

5. The branching of the primary roots.

6. The depth of tuber formation from the soil surface was recorded from 10 plants per every plot of the sub-experiment.

7. The dry matter weight of weed per 1 sq. metre per plot from every plot of the sub-experiment was estimated on 2nd, 19th July, 14th August, 1951.

Derived Data

From the above primary data, the following data

were derived. The changes which occur with age in the physiological process of the potato plant constitute a subject of considerable interest. Information of these changes may be obtained by the study of the following derived data.

(a) Efficiency Index.

(b) Ratio of the assimilating material to the total plant body.

(c) The proportion of tubers to the total dry matter or "storage efficiency".

Statistical Analysis and the Methods of the Presentation of Data

The data were subjected to the "analysis of variance" appropriate to the designs. For the yield data of the main experiment, there were two estimates of error applicable to (a) the effects of depth of planting, methods of cultivation and their interaction; (b) the effect of hand and no hand weeding between plants and their interaction with method of cultivation and depth of planting.

There is one estimate of error relating to method of cultivation and depth of planting and their interaction.

The methods of statistical analysis have not been described in detail. Reference may be made to Yates 1937 (54) for guidance on the subject. Percentages, that is moisture %, ware % were transformed to degrees $P = \text{Sin}^2 \phi$ (Fisher and Yates (14) and the figures were subjected to the proper analysis of variance.

The notations adopted by Yates is followed throughout; the main effects and interactions are denoted by capital letters and the treatments by small letters.

D Main effect of depth of planting
d_1 shallow planting
d_2 deep planting

H Main effect of hand weeding
h_0 no hand weeding between plants
h_1 weeds between plants were hand pulled.

D.H Depth x hand weeding interaction

The progressive data on number of leaves, weight of leaves, etc. were subjected to a proper analysis

and are graphically represented. The other information is recorded in the form of two-way tables on the basis of the statistical analysis, with the appropriate standard error in most cases. The difference is considered significant whenever the difference is greater than $\sqrt{2}$ S.E x t (Fisher and Yates 1949 (14).

Results significant at the 5% level of significance are marked with one asterisk*, and those significant at 1% level with two asterisks ** in the table of results.

The Sampling Procedure

The scheme of plant sampling method and growth on the main experiment was as follows. The sampling units were located independently and at random. Two units in every row of the five rows were under observation in every subplot of one replicate. The two guard rows were excluded. Every sampling unit consisted of five plants, one from every row. The two plants were chosen from every row at random. Every plant had a number. The two sampling units were as follows:- one consisted of the smaller numbers and the other of the bigger numbers.

N.B. The terms "units" and "sampling units" were used in the technical sense indicated:-
"Units" - the ultimate parts of a sample. One potato plant is considered as a unit in this study.
"Sampling Units" - those parts of a sample which were selected at random within the area to be sampled. Each consisted of five units in this study.

Size of the sample

Ten plants were selected at random from every sub-plot of 110 plants after allowing for edge plants and guard rows. The size of the sample is 9.9%.

Observations on the general development

Observations of sampling on successive occasions was recorded from fixed plants.

Sampling of the sub-experiment

Three plants were selected at random from every plot. One plant from every row after allowing for guard rows and edge plants.

Every plant was separated into stems, leaves and tubers for estimation of dry matter of plant parts.

Dry matter determination: The vegetative parts of the samples were dried in an electric oven at 95° - 100°C. for 24 hours.

Dry matter estimation of tubers: Two samples of about 600 gms. each were withdrawn from every treatment. One size of tubers (ware) was included in the samples. The tubers were cleaned with a cloth to remove the soil, cut into strips of about 1/8th inch cross section and put in the oven for 48 hours. If the duplicates differed by more than 1%, a further two samples were dried and the whole set averaged.

Rate of Plant Emergence

Effect of depth of planting on rate of come-up

To study the effect of depth of planting on rate of come-up, counts were made of plants at two day intervals, while they were coming up. As soon as the sprouts broke the ground and began to unfold their first leaves, they were counted as up.

The data relating to the effect of depth of planting on come-up of plants was subjected to statistical analysis. For this purpose a germination rate index (Bartlett 1937) was worked out for each plot.

The rate index is equivalent to the mean date of emergence. It employs experimental readings at all stages and summarises them by a single value. The analysis of variance shows that the effect of depth of planting on come-up was highly significant. (Table 1)

The plants coming up at the successive dates of observation were expressed as a percentage of the number which finally emerged in case of each treatment. (Table II) Table III shows the progress of sprouting under the shallow and deep planting at different periods.

Plants did not appear from the ground simultaneously owing to the difference in the state of growth of tubers at planting time and to the difference in the edaphic condition between different parts of the field.

Thirty-three days were required for 50 per cent

of tubers to come-up in shallow planting and 35 days in deep planting. Data show that after 31 days of sowing, about 20 per cent more plants had emerged from the shallow than from the deep planting.

To have a quantitative idea of the extent of delay with treatment depth of planting, the best criterion was to calculate the median date of come-up. This can be defined as the date on which 50 per cent of the stand is complete.

Date of emergence was 14th June and 16th June, 1951, for shallow planting and deep planting treatments respectively. Shallow planting required less time to come up than deep planting. This confirms Hardenburg's 1949 results, but contradicts Moore's 1937 results. This is because the moisture near the soil surface was low and high moisture in deep soil under Moore's experiment.

There was significant difference in number of plants came-up, in favour of shallow planting in all counting, except on 24th June, 1951, onward. That is due to the late appearance of plants planted deep.

The conclusion is that shallow planted plants come-up was more rapid than deep planted plants up to the 24th, then the deep planted caught up and when come-up was complete there was no difference in favour of any treatment. This shows that depth of planting has no effect on the establishment of potato plants.

Graphical Representation of Data

Detailed study of frequency distribution

I Percentage of number of plants which have come up by stated dates — Fig. 1.

II The frequency distribution of emergence (percentage frequencies) — Fig. 2

Fig. 1 shows the cumulative frequencies, that is the number of plants which have come-up by given dates for deep and shallow planting. The figure shows that the difference was wide at the start and the two lines become nearer and nearer with time. Fig. 2 shows the actual two days in cumulative percentage frequencies.

Effect of treatments on the final stand up of plants

At the end of the growth period, plants were counted, and the conclusion was that there was no difference in favour of any treatment studied, method of cultivation, depth of planting and hand weeding between plants (Table IV). This indicates that the cultural treatments under investigation have no effect on the final stand up of the plant.

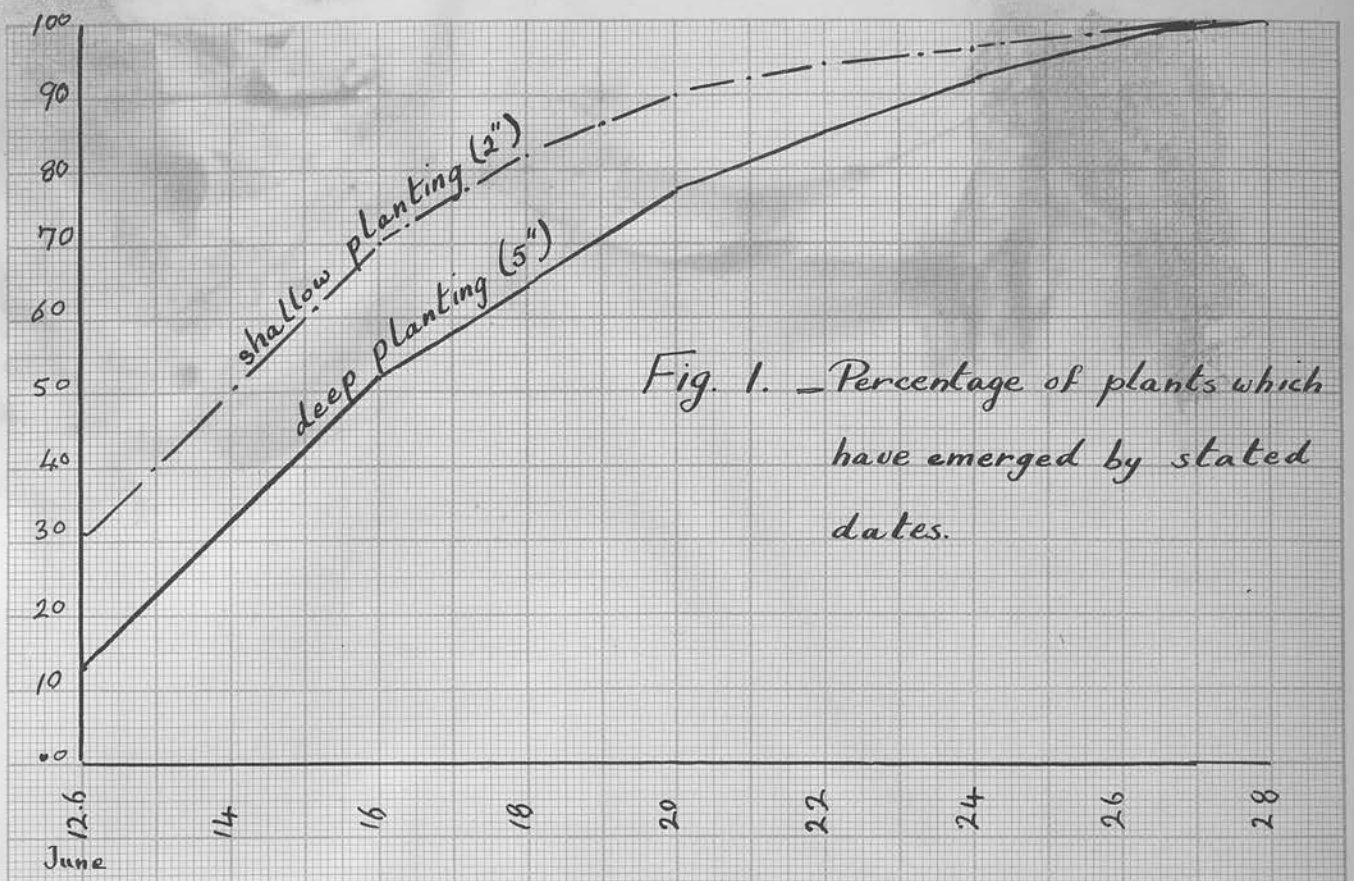


Fig. I. – Percentage of plants which have emerged by stated dates.

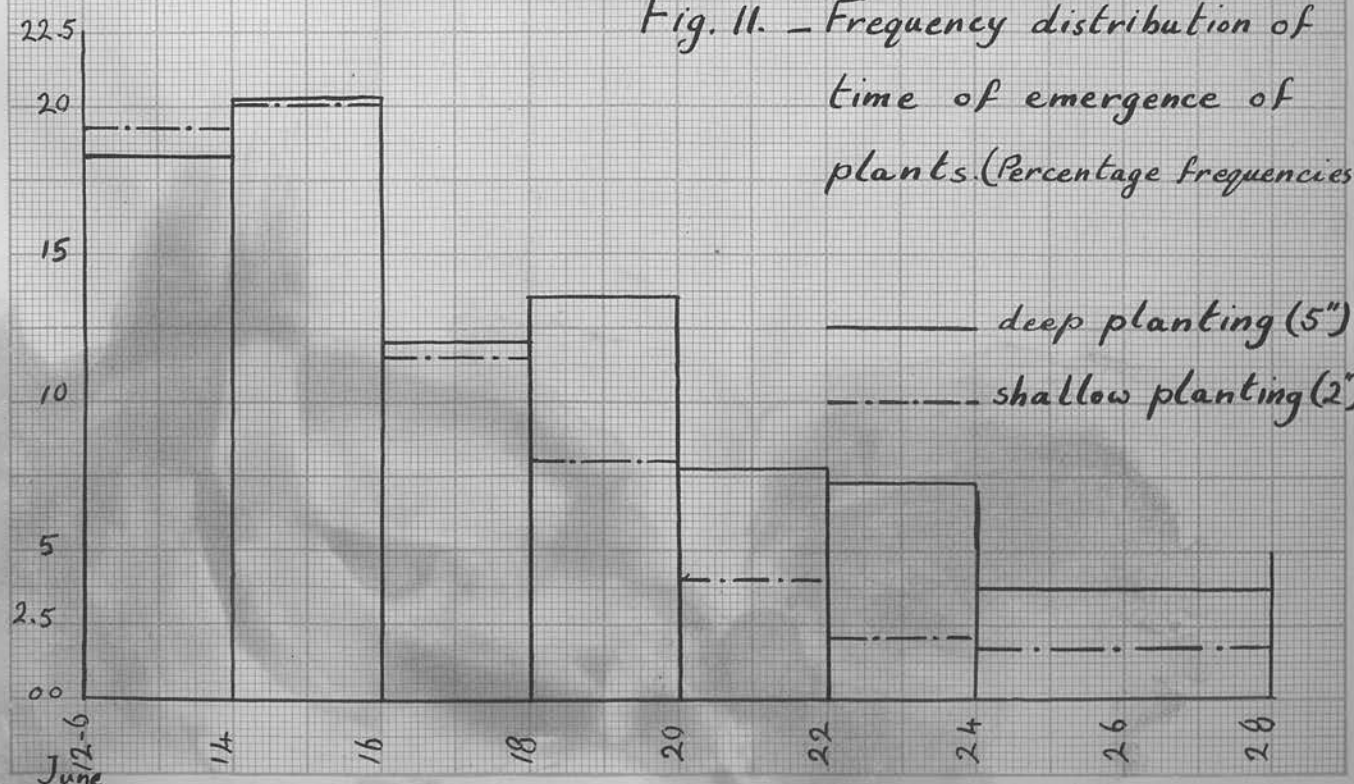


Fig. II. – Frequency distribution of time of emergence of plants. (Percentage frequencies.)

The Depth of Level of Tuber Formation

The depth of tuber formation is well shown in Tables IV and V.

Table IV shows clearly that most of the tubers tend to develop at a level of 2 and 4 inches from the soil surface. 47.4% and 45.1% of the total tubers developed are formed between 2 - 4 inches level from soil surface for two and five inches depths of planting respectively.

Down to three inches level from soil surface 61.2% of the total tubers developed when plants planted two inches depth and 65.1% down to four inches depth when planting was at 5 inches from soil surface (Table V).

When potatoes were planted at two inches deep, the tubers tended to form at a depth deeper than the seed was planted. When planting was at five inches depth, the tubers tended to form at a depth shallower than the seed was planted. It appears that tubers tend to form between 2.5 to 3.5 inches depth; this depth is influenced by depth of planting. This result confirms Zavitz 1916 results (56). This is a good indication that edaphic factors of soil moisture, temperature and aeration are the most favorable at this depth.

Detailed Study of Frequency Distribution of Tuber Formation for Depth of Planting

Since the main object of this section was to determine the average level of tuber formation

comparable between different depths of planting, depth of tuber formation is most simply defined as the depth where half of the number of tubers have been formed. That is to say, we take the median (while the median is the de pth by which half of the tubers have formed, the mean is the average depth obtained by multiplying each depth from soil surface by the number of tubers) of the frequency distribution.

It is found that the depth of level of tuber formation was 2.6 inch for the 2 inch depth of planting and 3.4 for the 5 inch depth of planting. More exactly, it is found:

	Median	S.E.	Mean	S.E.
2" depth of planting	2.6	.021	2.556	.017
5" " " "	3.4	.075	3.25	.06

B_2 and B_1 which are measures of Kurtosis and Skewness of the distribution have been obtained.

2" depth of planting	B_2	4.99	S.E.	.580
	$\sqrt{B_1}$	-.21	S.E.	.091
5" depth of planting	B_2	2.23	S.E.	.19
	$\sqrt{B_1}$	-.13	S.E.	.095

$$B_2 = \frac{\mu_4}{\mu_2^2} \qquad B_1 = \frac{\mu_3}{\mu_2^2}$$ (Tippett 1941)(48)

(μ_2 = the 2nd moment, μ_3 = the third moment, μ_4 = the fourth moment)

Standard error is calculated on basis of normality. The distributions therefore are: leptokurtic for shallow planting (2" depth of planting) and playkurtic for deep planting (5" depth of planting).

The distribution of the deep planting is not significantly skew. The distribution of the shallow

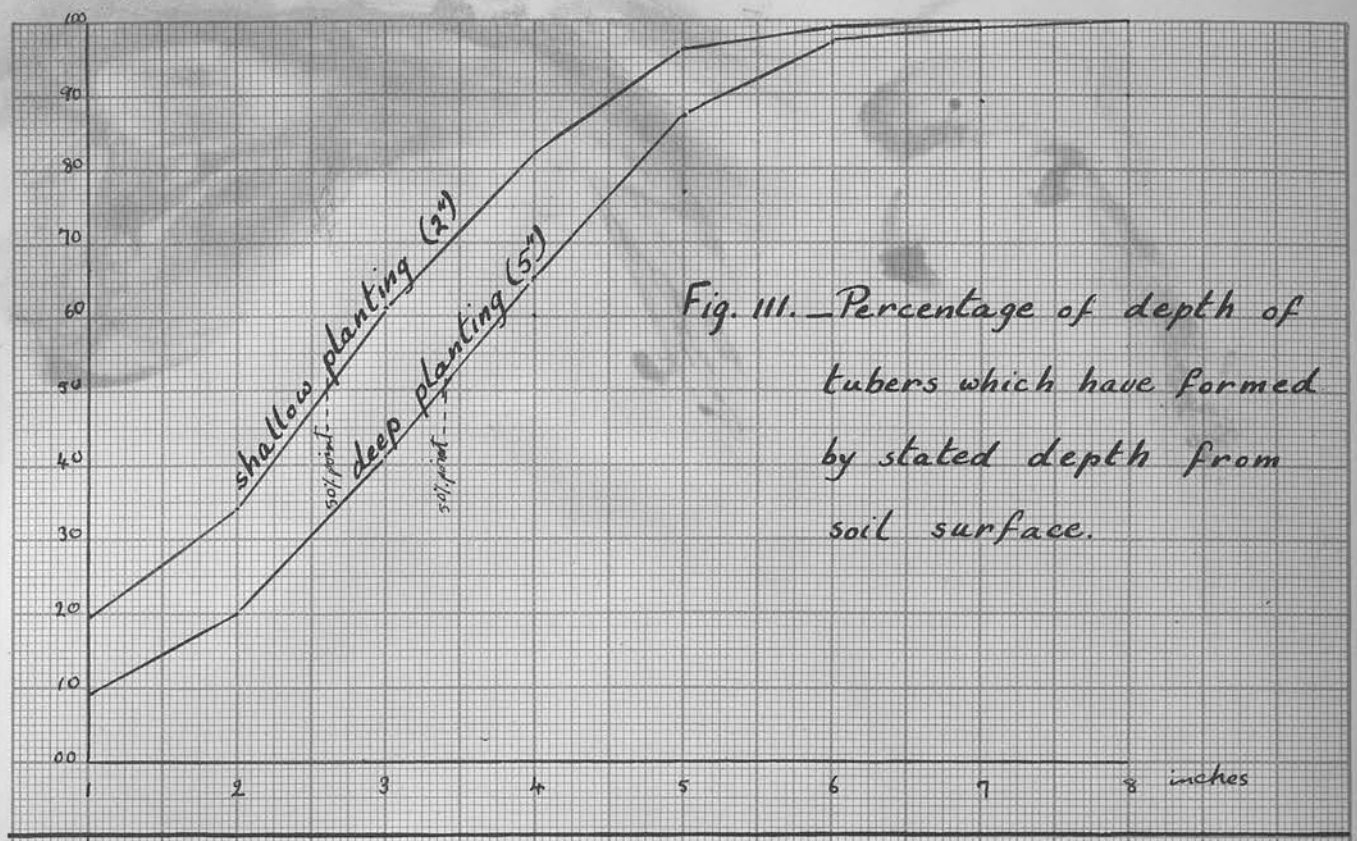


Fig. III. Percentage of depth of tubers which have formed by stated depth from soil surface.

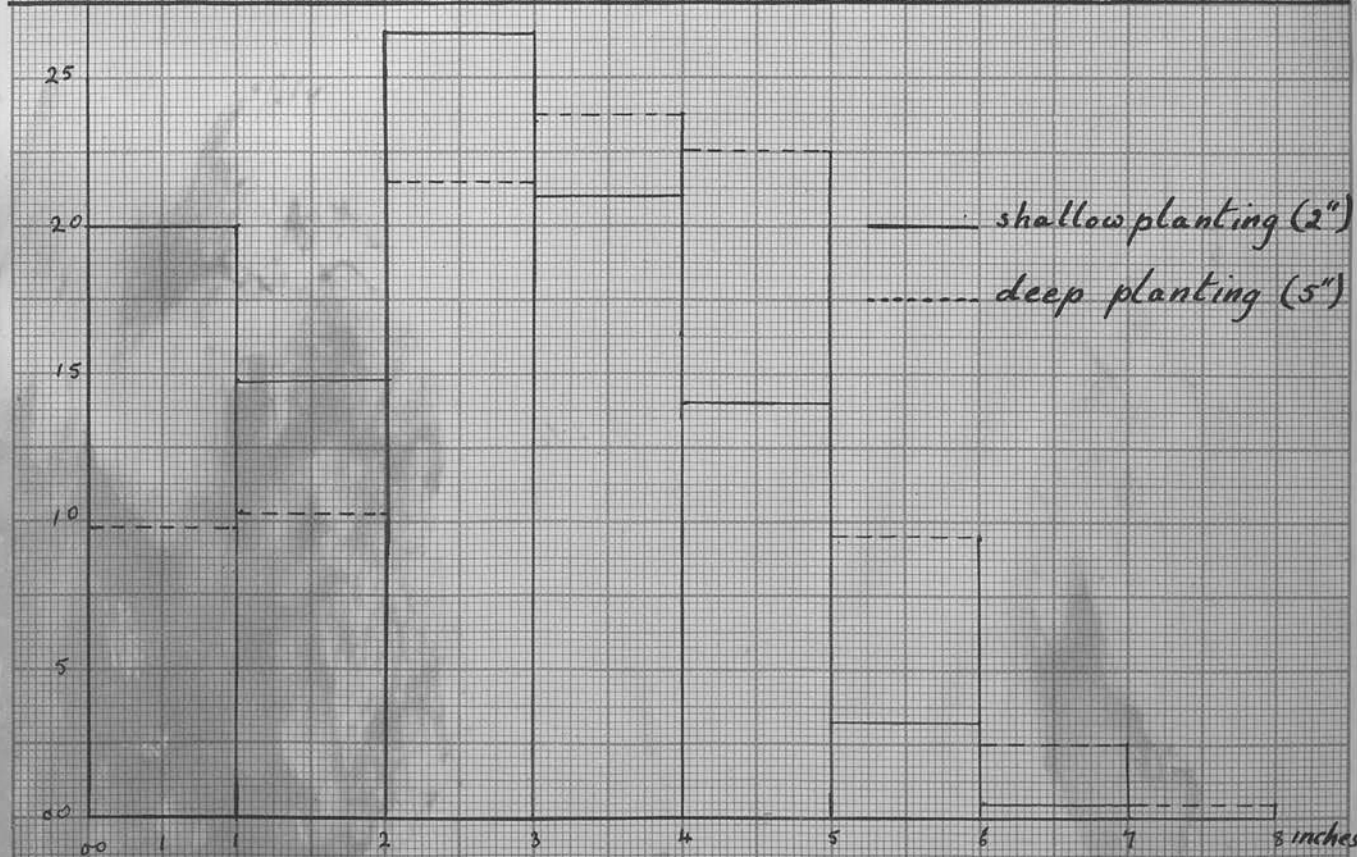


Fig. IV. Frequency distribution of depth of tuber formation.

(Percentage frequencies)

Effect of Cultural Treatments on Growth of Weeds

The object of this section is to examine how many weeds are killed by different methods of cultivation. A great problem thus arises, namely how badly do the weeds accumulate from year to year and how much do weeds depress the crop yield. This study is confined to the second problem. From investigation such as this, it could be possible to estimate how seriously a given weed population does reduce the crop yield. This point is of great importance in the Scottish mechanised crop husbandry.

The effect of the different methods of cultivation, under investigation, on the weed population during the potato growth season has been investigated by the three following methods, namely:-

(1) Eye estimate of weediness of the main experiment.

(2) Laying down a quadrat 1 x 1 sq. metre and counting the number of weeds of the main experiment.

(3) Estimation of dry matter of weeds per sq. metre in the sub-experiment.

Weed Dry-Matter Estimation Method

Method of cultivation and efficiency of weed destruction

The efficiency of different methods of cultivation in destroying weeds is different (Table VI). The treatments are arranged in ascending order according to their efficiency in destroying weeds (Table VIa)

No weeding

c_1 (narrow inter-row tillage) Inter-rwo cultivation 8" from the plant.

c_2 (wide inter-row tillage) Inter-row cultivation 6" from the plant.

h_2 hand weeding.

Hand Weeding

It was the most efficient method of weed destruction used. It eliminates weeds between ridges and between plants as well, where the tines of the cultivation cannot reach the weeds.

Width of inter-row tillage

The wide inter-row tillage destroyed more weeds than the narrow inter-row tillage. This is quite expected as wide inter-row tillage stirred more area of soil and so killed more weeds.

Unweeded plots

They had the largest amount of weed dry matter. Weeds were more vigorous than in any other treatment.

Time (Table VIa)

The dirtiness of plots are arranged in ascending order according to time as follows:-

t_1 first sampling

t_2 second sampling

t_3 third sampling

M.T. Method of Cultivation and Time of Sampling Interaction

Response of treatments to time (within treatments) (Table VIa)

I. Unweeded plots: The dry weight of weeds increased continuously with time although the difference between the first and the second sampling just failed to reach the significant level.

II. Hand-weeded plots: There was no difference

between different times of sampling. Plots were kept clean as weeds were pulled at the first and the second cultivation.

III. Cultivated treatments: Both wide and narrow inter-row cultivation showed a similar response. The dry weight of weeds per square metre at the second time exceeded that at the first and third sampling. Weeds were checked by cultivation after the second sampling.

IV. Response of treatments to time (Between treatments) The dry weight of weeds per square metre was less at all times of sampling in hand-weeded plots although the difference between it and wide inter-row tillage did not reach significance in first sampling.

V. The weedy plots had the highest amount of dry weight of weeds at all times, as weeds were not checked by hand-weeding or cultivation.

VI. The amount of dry weight of weeds of cultivated plots lie in between hand-weeded treatments and weedy treatments. The wide inter-row cultivation had less dry weight of weeds all the time although the difference just failed to reach the significant level at first and last sampling. This difference in favour of wide inter-row cultivation is due to the result of more destruction of weeds under wide inter-row tillage.

Eye Estimation of Weediness of Main Experiment

In the early growth period, weeds of unweeded sub-plots were vigorous and density was high and when they came to flower they were as tall as potato plants. Hand-weeded sub-plots were practically clean all the growing season.

Arranging the treatments in an order of most clean first and the dirtiest at the end, they would be as such: hand-weeded treatment, wide inter-row cultivation treatment, narrow inter-row cultivation treatment, and last of all the unweeded uncultivated treatment.

Quadrat Method (Main Experiment)

The number of weeds estimated within a frame of 1 x 1 sq. m. per sub-plot was counted. Analy sis of variance is shown in Table VII. There is difference due to method of cultivation, time and hand-weeding. Treatments are arranged in ascending order due to method of cultivation, as follows:-

Wide inter-row cultivation

Narrow " " "

There was no difference between c_4 and c_3 or between c_2 and c1; that was because the third additional inter-row cultivation was not employed at this time of counting.

The wide inter-row tillage destroyed more weeds than the narrow inter-row tillage as the former stirred more area of soil.

Periodicity of Weed Seed Germination

The germination requirement for weeds was best met by the conditions prevailing at the early stages of the potato plant development and before its emergence.

The number of weeds germinated per sq. metre between 23rd June 1951 and 2nd July 1951 for different treatments was as follows:

a) 8 uncultivated un-hand-weeded treatments
b) 28 " hand-weeded "
c) 15 cultivated treatments.

In clean sub-plots (c_0h_1) the cumulative number of weeds germinated between the first and the second counting was far more than that of dirty sub-plots (c_0h_0). This could be due to the factor that the first plant to occupy any area of soil, small or large, tend to exclude the others. The soil between rows in dirty sub-plots was packed by weed roots.

In cultivated plots, the cumulative number of germinated weeds was more than that of uncultivated un-hand-weeded sub-plots (c_0h_0). This conclusion is due to that, tillage induces germination of dormant seeds through improving the aeration of the soil.

The mechanism of cultivation is to stir the soil and so weed seeds are induced to sprout and those weeds already sprouted are destroyed.

Most of weed seeds germinated before and at the same time as potato germination; thus the weed top growth and their root system coincided with the foliage and root development of potatoes.

Thus the competition of weeds with the potatoes started at the beginning of the potato development. Weed species in the field were Poa annua, Dactylis glomerata, Brassica sinapsis, Agropyron caninum, Tanacetum vulgare, Plantago major.

After the potatoes emerged, they suppressed weeds for their high shading power and their roots filled the upper surface of the soil.

Vegetative reproduced weeds renew themselves from vegetative parts kept under the ground. At the later stages of the potato growth season, these weeds were pale and easily hand pulled. This is due partly to the suppression effect of potatoes and partly to the exhaustion of food stored in underground parts due to the repeatedly destruction of the vegetative parts in hand-weeded sub-plots and in cultivated plots as well.

The second cultivation killed 56.9% and 68.3% of the total number of weed seedlings by narrow and wide inter-row cultivation respectively. In the third cultivation the per centage kill was 9.9 and 15.9 for narrow and wide inter-row cultivation respectively.

The second inter-row cultivation destroyed more weeds and was more efficient than the third inter-row cultivation as at the second time of cultivation weeds were many and distributed on furrows as well as on ridges. At the time of third cultivation the number of weeds was small and they were mostly distributed in places (between plants) where tines

cannot reach them.

The wide inter-row cultivation was much more efficient in destroying weeds on the second as well as on the third cultivation than the narrow inter-row cultivation.

The wide inter-row cultivation stirred more soil and destroyed more weeds than the narrow inter-row cultivation.

ROOT STUDIES

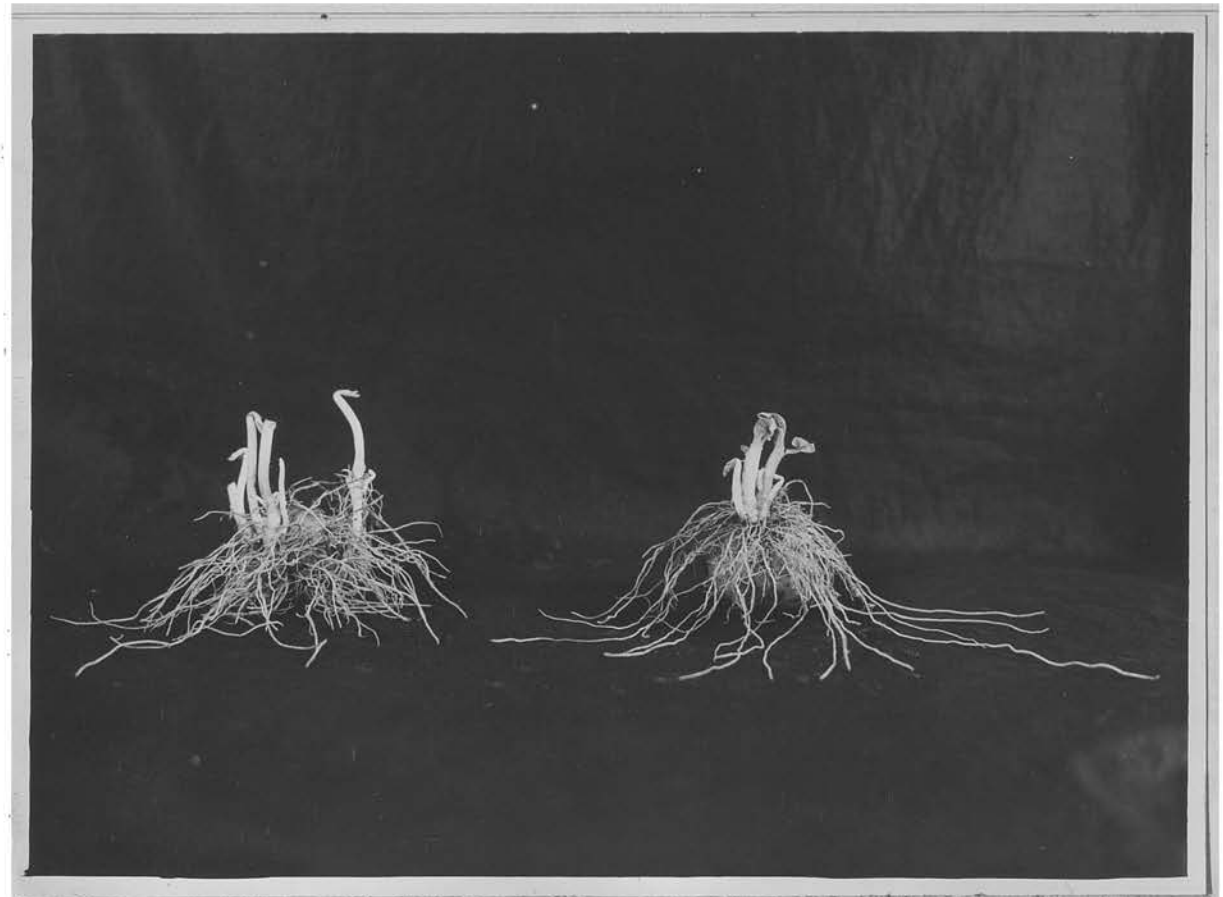
The cultural treatments (depth of planting, methods of cultivation) exert a marked effect upon habit maximum depth, lateral extent of root systems and often upon yield.

Herein is a report of a study made of the potato root system at various times from planting potatoes, in order to determine whether or not the root distribution would throw any light on the difference in response to cultivation exhibited by the potatoes.

In this study three methods were used. In one of them digging alone was employed to determine the maximum depth reached, the lateral extent of the root at the various growth stages of the potato plant. In the second, the soil was dug and the soil was washed away, leaving the roots exposed so that they could be photographed to show the general distribution and growth of the roots. This method was employed in the first excavation only, as it was difficult to get water to the field.

In the third method, a quantitative analysis of root system was employed. In this, roots were excavated and then stored in 3% formaldehyde in glass jars for quantitative analysis at convenient time. Branching of roots was studied.

To determine the maximum depth reached by the root system at any given time, a trench was dug as deep as possible to allow one to begin digging from under the rows at the bottom of the trench and working back under the plant and upward towards the surface.



Deep Planting Shallow Planting

Plate III. : Soil about the mother-tuber was thoroughly filled with roots. (19 days after planting)

investigation on the diagonal course of main roots on ridge culture. Main roots showed a tendency to grow diagonally up to 20 cms. from the stem, then to grow rather abruptly downward. It should be stated that a small number of main roots (10 - 12) showed a tendency to grow rather abruptly downward. It is observed also that there are practically few roots just under the plant (the mother tuber).

The close proximity of the roots to the soil surface, many being confined to the first three inches, should be taken into account in tillage practice.

Whether planted deep or shallow, cultivated plots had few roots in the soil area stirred by cultivation, whereas in hand-weeded plots and uncultivated plots, the roots grow to within 2 cms. of the soil surface.

The primary main roots were densely covered with thread-like laterals. The secondary branches were varying in length from 1 cm. to 15 cms. The secondary roots were so numerous that soil surface was practically occupied by them.

The general character and distribution of old plants was almost identical with that of young plants. The difference is due to the extent of the root system.

The young roots were white but as they age they turn brown as a result of the suberization of the outer layers, that is, a corky material being deposited around them. This holds true for the

single root as its tip is white, its older part is brown corky.

Roots belonging to different treatments showed close resemblance so far as suberization of young roots is concerned.

Lateral Extent of the Root System

Potato root system showed a tendency to grow outward parallel to the surface of the ridge and then grow abruptly downward. Lateral extent was measured four times at about a fortnight's interval throughout the early part of the growing season and during the active period of cultivation.

Depth of Planting

In the early stages of the plant growth and before the plants came up and before any cultivation adopted, potatoes were dug to see if there is any difference due to the two depths of planting. On 8th June, 1951, the lateral extent of the root systems of plants was 24 and 15 cms. for plants planted 2 inches and 5 inches respectively. The lateral extent of the root system of shallow planting (Plate IV) was more than that of deep planting (Plate V) by about 9 cms. This is shown clearly in the Plate Iv. This difference is the result of the early activation of shallow planted tubers, as was expressed by the plants coming up two days in advance.

In the second digging of roots, this difference became narrow as the root system of the deep planted tubers grew rapidly and caught up with that of the

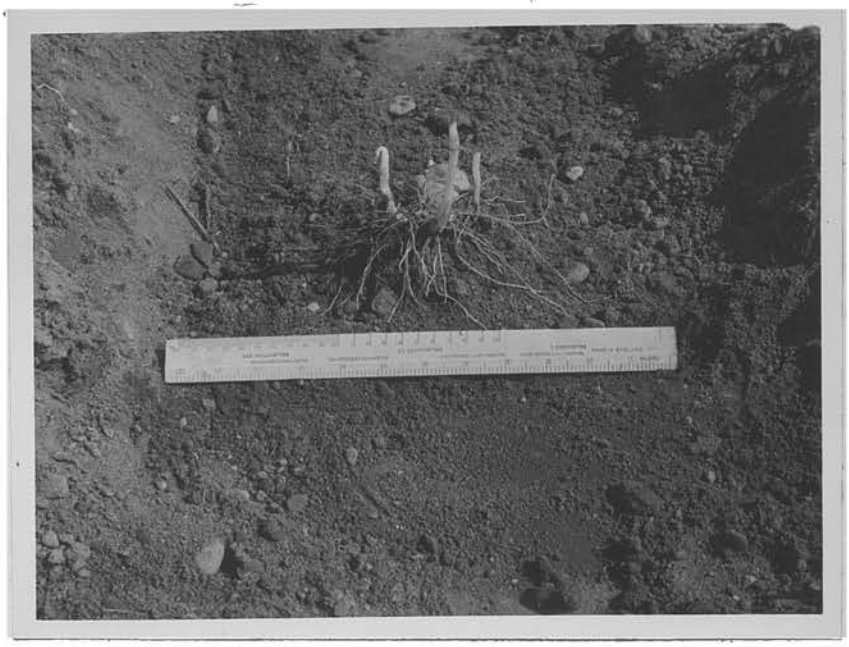


Plate IVb. : Lateral extent of the root system of deep planted plant, 19 days after planting.

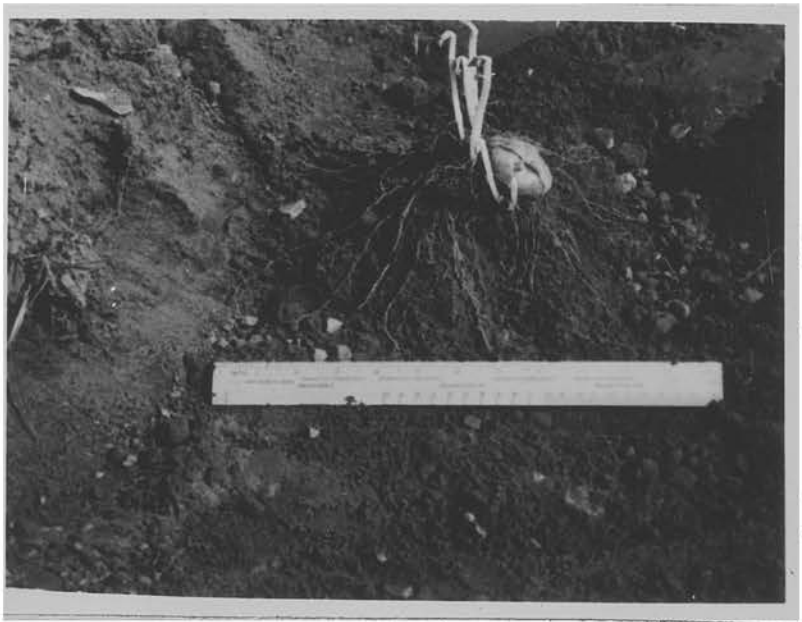


Plate IVa. : Lateral extent of the root system of shallow planted plant, 19 days after planting.

shallow plantings and the difference became statistically insignificant (Table VIII). In the third and fourth digging, the data show that there is no difference in lateral extent of roots in favour of any depth of planting treatments.

Cultural Treatments (Table VIII)

The data show that a significant difference existed due to:-

(i) Method of cultivation

(ii) Time of sampling

(iii) Method of cultivation x Time of sampling interaction M x T.

Time This simply means that the lateral extent of the root system increased with time as plants were growing.

Lateral extent is arranged in ascending order as follows:- (Table VIIIa)

t_2 (29th June, 1951)
t_3 (13th July, 1951)
t_4 (2nd August, 1951)

Method of Cultivation

Treatments are arranged in ascending order. (Table VIIIa). When difference did not reach the significant level, treatments are written on the same line.

wide inter-row tillage treatment $>$ unweeded treatment

narrow inter-row tillage treatment $<$ unweeded treatment

hand-weeded treatment

Effect of Weed Competition on Root Lateral Extent

Comparison of plants of hand-weeded plots with

lateral extent of unweeded plots shows the effect of weed competition on the lateral extent. Data show clearly that weed competition restricts the lateral extent of the root system. This confirms the work on other crops. Weaver and Kramer 1932 (50), Yocum 1937 (55), Coile 1940 (10).

Rate of growth of the root system in weedy plots is smaller than that of hand-weeded plots because the former suffer from competition with weeds and have less carbohydrates transferred to the root system.

Effect of Width of Cultivation on Root Lateral Extent

The difference between c_1, c_2 treatments shows this effect. It is unquestionable that tines cut the surface-feeding roots in disturbed soil and so it is quite expected that the nearer the cultivating tines are to the plant, the more roots are liable to be cut. This is shown by significant difference between narrow and wide inter-row cultivation.

Lateral extent of plants of hand-weeded plots was restricted neither by weed competition nor by destruction of tines; this is shown by the difference in extent between h and c_1, c_2 in favour of h.

The roots were cut in the disturbed soil of inter-row tilled plots. The destroyed roots in these plots were smaller in the first inter-row tillage than in the second. This is because the extension of roots between rows was more than at the first time of cultivation.

Lateral Extent of Root System
M.T. (Table VIIIa)

Response of Treatments to Time (within treatments)

I In hand-weeded plots roots were growing freely and not restricted either by competition of weeds or by harm effect of tines. The significant difference existed between the three different times of sampling. This shows that roots were extending laterally all this period.

II Under inter-row cultivated treatments potato roots at the fourth time was longer than at both the second and third excavation.

There was no significant difference between the third and second sampling; this is due to the destruction of roots at the second cultivation which was done between third and second excavation. More roots were destroyed at the wide inter-row treatments than at the narrow inter-row cultivation.

III The roots under weedy treatments were growing continuously.

Response of Treatments to Time (between treatments)

IV Hand-weeded plots, the root system showed the most extensive root system over all other treatments under this study, at all times of excavation, but the difference between it and c_0, c_1 in the second excavation and c_0 at the third excavation and c_2 at the fourth excavation did not reach the significant level.

V There was a significant difference between c_1 and c_2 in favour of c_1. This holds true at the second and third excavation. At the fourth excavation the

arrangement was changed and c_2 became more extended than c_1 although this difference failed to reach significant level.

VI Unweeded plots, the lateral extent was longer than c_2 in the second excavation. At the fourth excavation the difference was in favour of c_2. The lateral extent was less than c_1 in the second excavation and longer at the third and less at the fourth excavation, but the difference at second and third excavations never reached significance.

It should be noted that tines do not interfere with the part of the root system within rows and between successive plants but interfere with that part of the root system within furrows. The distance between successive plants and rows is 14 and 27 inches respectively. Root systems between successive plants overlapped before root system of plants of different rows. The overlapping between successive plants and rows was on about 29th June and 2nd August, 1951, respectively.

Three or five roots arise f rom behind the cut end of roots and these branches took the expected direction of the main root.

Fig.V shows the general trend of increment in the lateral extent of the root systems, under different methods of cultivation.

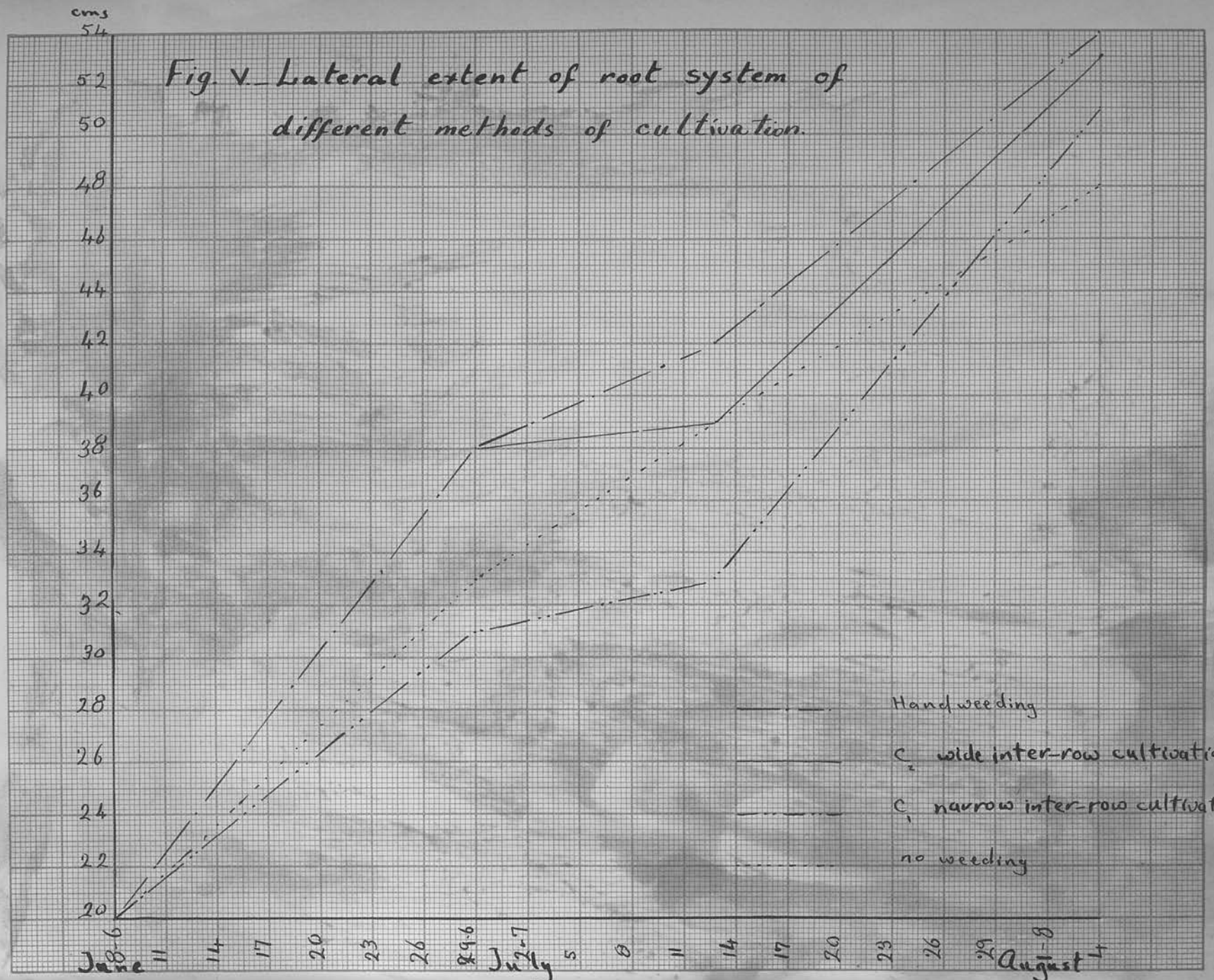


Fig. V. Lateral extent of root system of different methods of cultivation.
cms
54
52
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
June
11
14
17
20
23
26
29
July
5
8
11
14
17
20
23
26
29
August
1
4
Hand weeding
C2 wide inter-row cultivation.
C1 narrow inter-row cultivation.
no weeding

Maximum Depth of the Root System

The maximum depth of the root system was measured at the same time as measuring the lateral extent.

The shallow planted plants began their growth actively before deep planted plants. This is expressed in the deeper penetration of shallow planted plants in the first digging.

The data show that there is a significant difference due to the following factors: method of cultivation and time of sampling. The difference due to M.T., M.D., D.T., M.D.T. and D. failed to reach the significant level (Table IX).

Time (Table IXa)

There is a significant difference between the different times of digging, in favour of late digging. This is simply because plants were growing and roots go deeper in the soil. They are arranged in ascending order as follows:-

			1951
t_1	2nd excavation of root system		(29th June)
t_2	3rd " " " "		(13th July)
t_3	4th " " " "		(2nd August)

Method of Cultivation (Table IXa)

(a) Effect of weed competition on maximum depth of roots

The comparison of hand-weeded plots with unweeded plots shows the effect due to the competition of weeds. The data show that there is difference in favour of hand-weeded plots. This indicates that weeds restrict the growth of the root system.

(b) Effect of pruning on maximum depth of roots

The comparison of h, c1, c2 with each other shows this effect. The roots of hand-weeded plots were deeper than cultivated plots. This result stands against the deep-rooted farmers' belief that pruning of roots is conducive to a deeper penetration by the remaining unpruned roots. On the contrary, unpruned roots (hand-weeded plot plants) were deeper than the pruned ones. This confirms Moore's result 1937.

The conclusion is that the soil volume filled by roots of hand-weeded plots was bigger than that of cultivated plots as the latter was diminished in both the surface, extent and the subsoil. Such cultivated plants would make less use of fertilizer in the surface especially if fertilizer was broadcast.

Effect of width of cultivation on maximum depth of root system

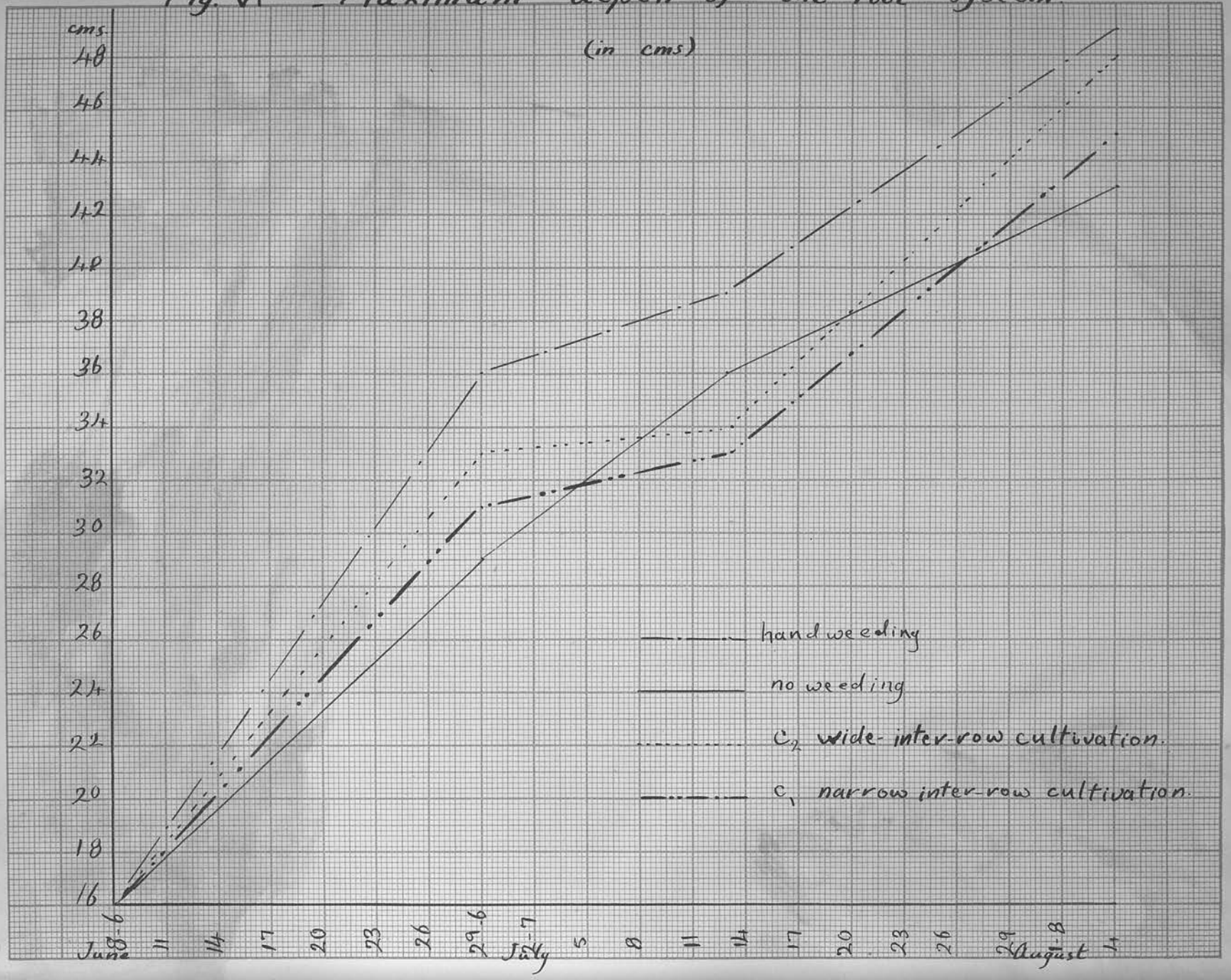
The maximum depth reached by wide inter-row tillage was less than that of narrow inter-row tillage.

The maximum depth of the root system under different cultural treatments is shown graphically in Fig. VI.

Root Volume

It is the volume of soil containing roots. It is stated above that clean plots have bigger root volume as both lateral extent and maximum depth are restricted in comparison to clean plots. In cultivated plots, lateral extent, maximum depth are restricted, also the stirred soil is almost devoid of roots.

Fig. VI - Maximum depth of the root system.



Root Branching

As it is practically impossible to estimate the total number of secondary roots per plant directly, a sample method was adopted. The number of secondary roots coming out per 1 cm. of primary root is considered as branching. A branch of a root floated in a black tray of water, to show detail of branching (Plate V) and to make the counting of branches easy. The analysis of variance show that the cultural treatments under examination has no effect on branching of roots (Table X). No change due to depth of planting, soil mulch, root pruning, weed competition could be attained. The average number of secondary roots coming out of 1 cm. primary root are shown in Table Xa.

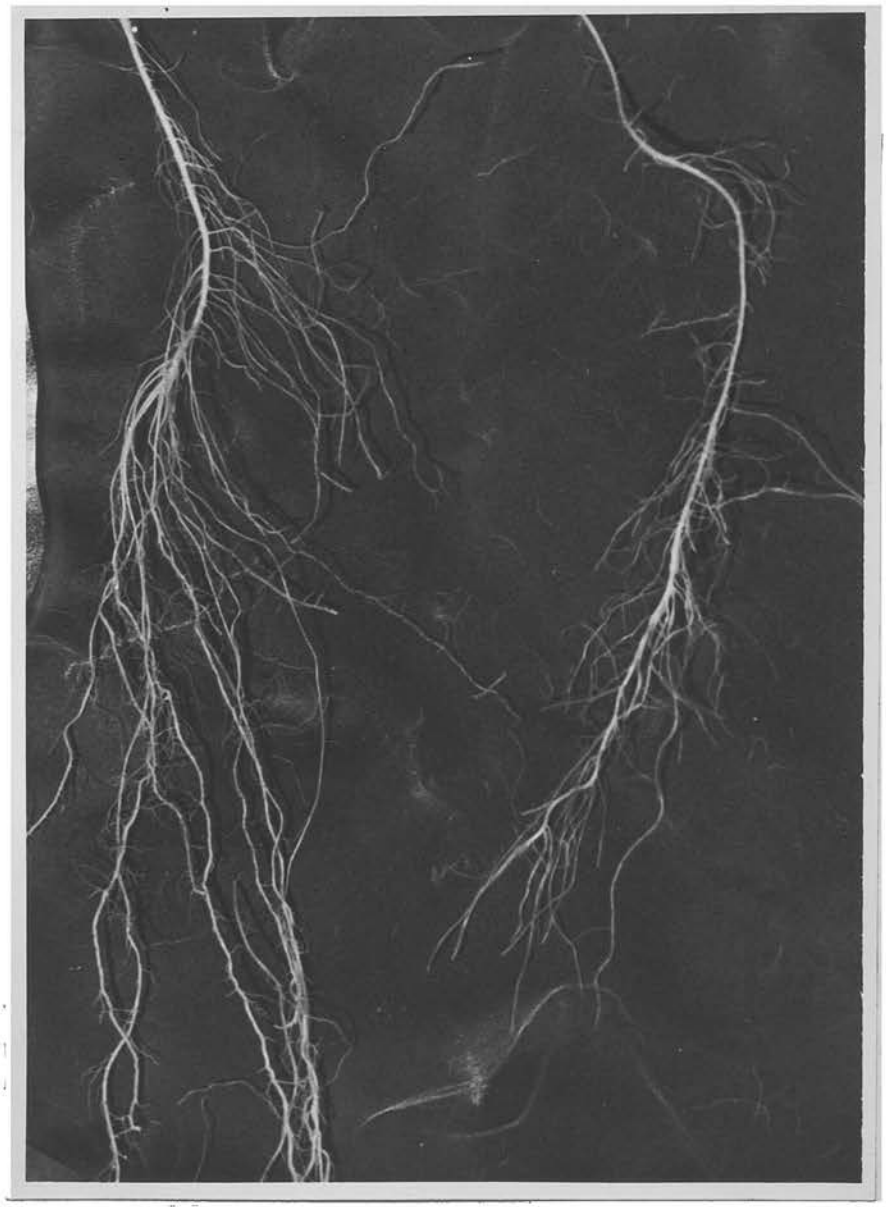


Plate V. : Portions of a primary root floated in a tray of water, showing detail of branching.

Statistical Analysis of Results of Estimation of Dry Matter of stems, leaves and foliage (stems + leaves)

Table XI contains the analysis of variance of stems, leaves and foliage on dry weight basis.

There is a significant difference due to method of cultivation, time and method of cultivation.

Time interaction

This interaction is important here, in this study, because it indicates that there is difference in growth rate.

Dry weight of different parts of foliage

Dry weight of the plant or its parts provides the best summary of growth. Two items of information are required from the dry weight data:-

(i) Did the cultural treatments result in a significant amount of vigor?

(ii) Had the different methods of cultivation an effect on the growth rate of the plant.

The analysis of variance of the value of the dry weight provides this information. The complete analysis of variance of dry weight of different parts of the plant are shown in Table XI, and the results of this analysis are summarised in the following table.

Table XII

Summary of the Analysis of Variance of Stems, Leaves, Foliage

Significance (S) is assumed when the value of F exceeds the 1% level.

Due to	Stems	Leaves	Foliage
Method of cultivation (M)	S	S	S
Depth of planting (D)	-	-	-
Time of sampling (T)	S	S	S
Replicate	-	-	-

Table XII contd.

Interaction:	Stems	Leaves	Foliage
M. D.	-	-	-
M. T.	S	S	S
D. T.	-	-	-

The entries in the above table will be considered in turn. The variance due to methods of cultivation is significant in each of stems, leaves, foliage. This means that the method of cultivation in each of stems, leaves, foliage differed in the mean dry weight. It has to be determined next where these differences lie. From the analysis (Table XI a, b, c) it is clear that the significant difference in dry weight between different treatments of methods of cultivation is distributed in ascending order as follows:-

Stems	Leaves	Foliage
c0	c0	c0
c1 c2	c1 c_2	c1 c_2
h	h	h

The conclusion from this analysis is that the plants of hand-weeded plots showed significant foliage vigour. in stems, leaves and foliage, measured as dry weight. These results of stems and leaves are set out as graphs in Figs. VII, VIII. This difference is due to the full freedom of the growth without any competition with weeds or without any hindrance of growth due to pruning.

Unweeded plots gave less weight both in stems, leaves and foliage. This stunted growth is due to

Fig. VII. Dry matter of stems per plant.

(in gms.)

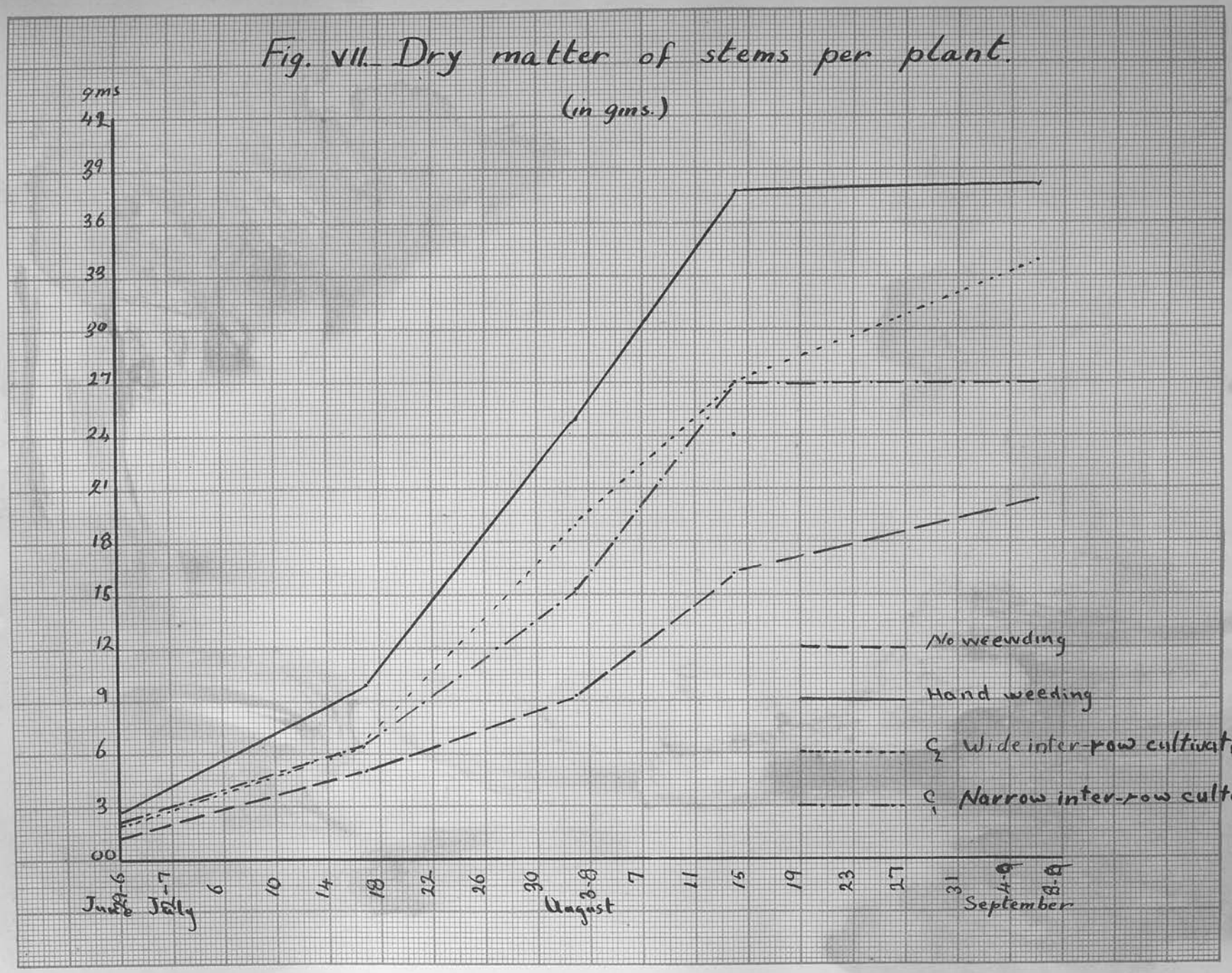
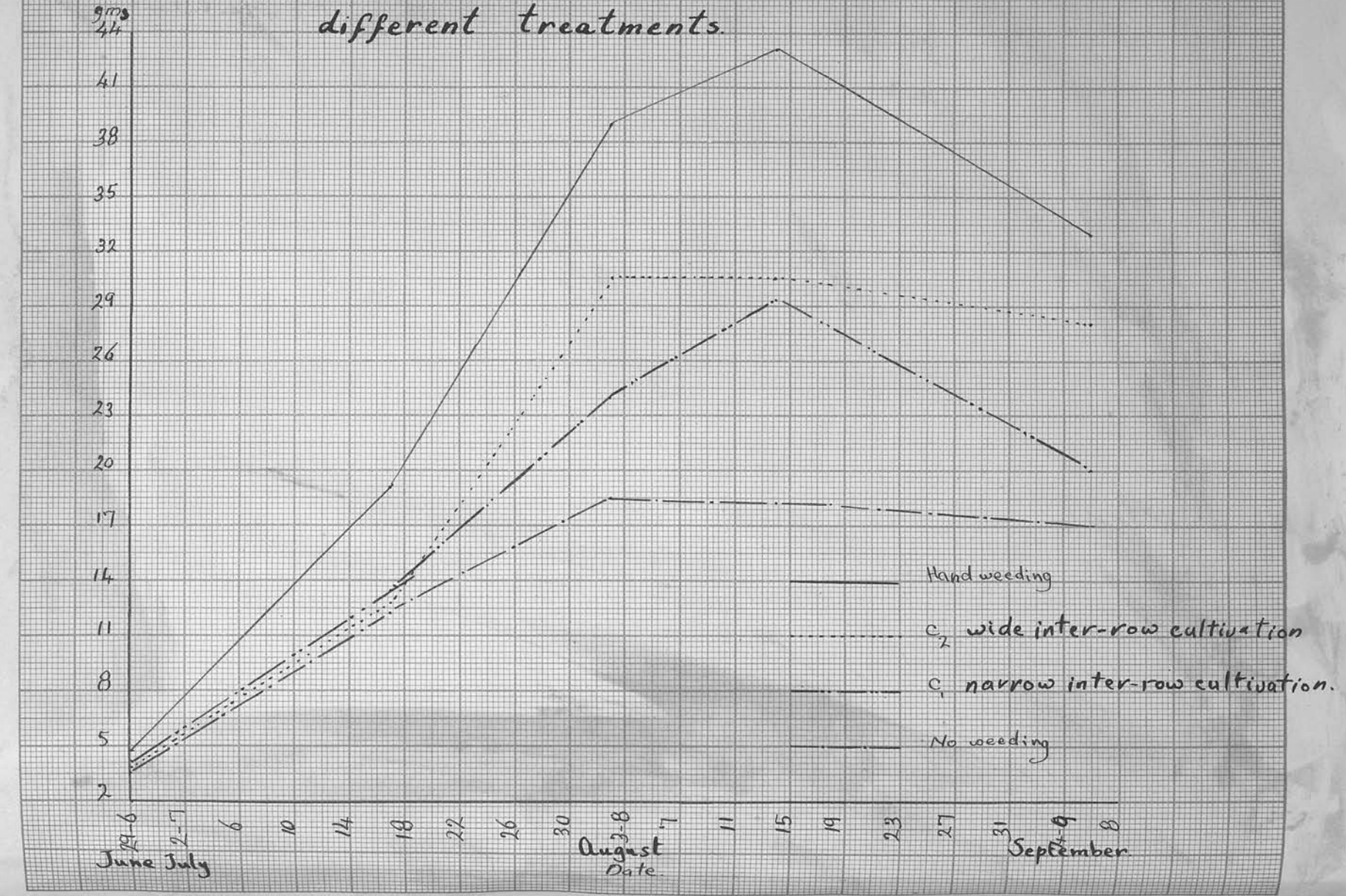


Fig. VIII. Dry weight of leaves per plant under different treatments.



the competition of weeds with the crop and the difference between hand-weeded plot plants and unweeded plot plants shows the effect of weed competition on growth.

Cultivated plots lie in between hand-weeded plots and unweeded plots. There is difference between narrow and wide inter-row cultivation in leaves, foliage and stems in favour of wide inter-row cultivation, but the difference in stem dry weight did not reach the significant level.

Turning next to the entry in Table XII, depth, there is no significant difference due to depth of planting.

Variance due to time, the next entry in the Table, is of course highly significant; it simply means that the plants are growing. The dry weight of plants is arranged in ascending order due to their significance in the following order:-

1951	Stems	Leaves	Foliage
(29th June)	t_1	t_1	t_1
(13th July)	t_2	t_2	t_2
(2nd August)	t_3	t_5	t_3
(14th August)	t_4	t_3	$t_4 > t_5$
(6th September)	t_5	t_4	

Dry weight of stems of plants increased continuously with time during the five sampling times as part of the food synthesized in leaves translocated to increase stem weight. At senescent time, stems were observed to wilt, turn yellow and die as food stored in them translocated to tubers.

Dry weight of leaves increased continuously from the first sampling up to the fourth sampling, then the leaves weight tended to constant and after that leaves became yellow, shed and the total weight of leaves decreased.

Foliage (stems plus leaves) dry weight increased continuously up to the fourth sampling, then it tended to decrease although this difference did not reach significance between fourth and fifth sampling. The increase in weight of stems at $t_3 - t_4$ outweighed the constant weight of leaves ($t_3 - t_4$) and this was reflected on total foliage weight by an increase from t_3 to t_4. The shedding of leaves from t_4 to t_5 outweighed the slow increase of stems from t_4 to t_5 and the foliage weight decreased, although this did not reach significance.

The next entry, the interaction M.D., is not significant.

The next entry, the M.T. interaction, is significant. This factor is important, for any difference in growth rate will be considered as a significant variance under this heading.

The D.T. interaction is not significant.

Method of Cultivation x Time of Sampling Interaction of the Stem Dry Weight of the Plant T x M

(Table XIa)

Response of treatments to time (within treatments)

I. Hand-weeded plots: Stems dry weight per plant increased with time, but the difference did not reach significance between fourth and fifth sampling. The dry weight of stems tended to be constant between t_4 and t_5.

II. Unweeded plots: The dry weight of stems per plant increased with time. The difference failed to reach significance between the following periods:- $t_1 - t_2$; $t_2 - t_3$; $t_4 - t_5$.

III. Wide inter-row cultivation treatment: It increased with time. The significant difference was not established between t_1 and t_2.

IV. Narrow inter-row cultivation treatment: The response of the stem dry weight of a plant to time was typically the same as under wide inter-rwo cultivation. But the stems tended to be constant between the fourth and the fifth time of sampling.

Response of treatments to time (between treatments)

I. Hand-weeded plots: The stems dry weight per plant was higher than that of other treatments at all times of sampling although the difference did not reach the significant level at first and second sampling.

II. Unweeded plots: It had the smallest dry weight of stems per plant but the significant difference never existed between it and other treatments in both the first and the second sampling. This fall in weight is due primarily to competition of weeds.

III. Cultivated treatments: The difference was insignificant in favour of wide inter-row cultivation in the first three sampling times, then they tended to be equal but the difference reached significant level at the fifth sampling in favour of wide inter-row cultivation. This difference between wide and narrow inter-row cultivation is due primarily to the more competition of weeds with the plants of narrow inter-row cultivation.

Leaf Dry Weight of a Plant

Method of Cultivation x Time of Sampling Interaction

(Table XIb)

Response of leaves dry weight of a plant to time: (within treatments)

I. Hand-weeded plots: The weight of leaves per plant increased with time during the first three sampling periods. This is due to the formation and enlargement of leaves. Then the weight of leaves tended to be constant between t_3 - t_4. After that, the leaves shed, and this was shown by the significant difference between the weight at t_5 and t_4 in favour of t_4.

II. Unweeded plots: The weight of leaves per plant increased wit h time throughout the first three sampling periods. It tended to decrease throughout the last two sampling periods although the difference did not reach the significant level.

III. Cultivated plots: The weight of leaves increased with time during the first four sampling periods although the difference failed to reach the significant level between t_3 and t_4 when weight of leaves of a

plant tended to be constant. Then the weight decreased although the decrease did not reach the significant level in wide inter-row cultivation.

Response of leaves dry weight of a plant to time: (between treatments)

I. Unweeded plots had the lowest dry weight of leaves per plant. The difference did not reach significant level between it and other treatments in the first and second sampling, except hand-weeded treatment.

II. Hand-weeded plotss Plants had the highest dry weight of leaves although the difference did not reach significant level at the first sampling.

III. Wide inter-row cultivation: Plants dry weight was less than the narrow inter-row cultivation but the difference was not significant. At the last sampling, there was difference in favour of wide inter-row cultivation. The difference at the fourth sampling did not reach significant level.

Foliage Dry Weight of a Plant : M.T.

Response of foliage to the change in time: (within treatments)

I. Unweeded plots: Foliage weight increased with time. The difference failed to reach the significant level between t_2, t_3. The weight of foliage tended to be constant between t_3 - t_4 - t_5. The foliage growth period was short.

II. Hand-weeded plots: Foliage increased in weight during all sampling periods although the difference did not reach the significant level between t_4 and t_5. It is shown that the foliage growth period in hand-

weeded treatment is larger than in unweeded treatment. Plants of hand-weeded plots did not suffer set back due to competition.

III. Cultivated plots: The foliage weight increased with time during all sampling periods. In wide inter-row cultivation treatment, there was no significant difference between $t_3 - t_4$, $t_4 - t_5$. In narrow inter-row cultivation treatment difference failed to reach the significant level between $t_4 - t_5$.

Response of plants to time (between treatments):

I. Unweeded plots had the smallest foliage weight at all the sampling times. The difference did not reach the significant level in first sampling; in the second sampling there was no significant difference between c_0, c_2, c_1, and in the fifth sampling there was no significant difference between c_0 and c_1.

II. Hand-weeded plots had the highest dry weight of foliage at all times. The difference failed to reach the significant level in the first sampling. In the fifth sampling, no significant difference between c_2 and h was shown.

III. Cultivated plots: There was a significant difference at the third and fifth sampling between wide and narrow inter-row cultivation in favour of the former.

Number of Leaves

The counts of number of leaves of the fixed sample of 10 plants per subplot of the main experiment give only a measure of the balance of the rate of production and death of leaves. The change in number of living leaves present per plant are shown graphically in Fig. IX.

Depth of planting

Early in the growth period of the potato plants, shallow planted tubers had more leaves than deep planted tubers. This was the result of the early unfolding of leaves. Number of leaves per plant on 26th July, 1951, was 40.07, 37.15, for shallow and deep planting respectively. This difference narrowed and on the second counting the difference failed to reach the significant level. The difference was kept insignificant in the third counting.

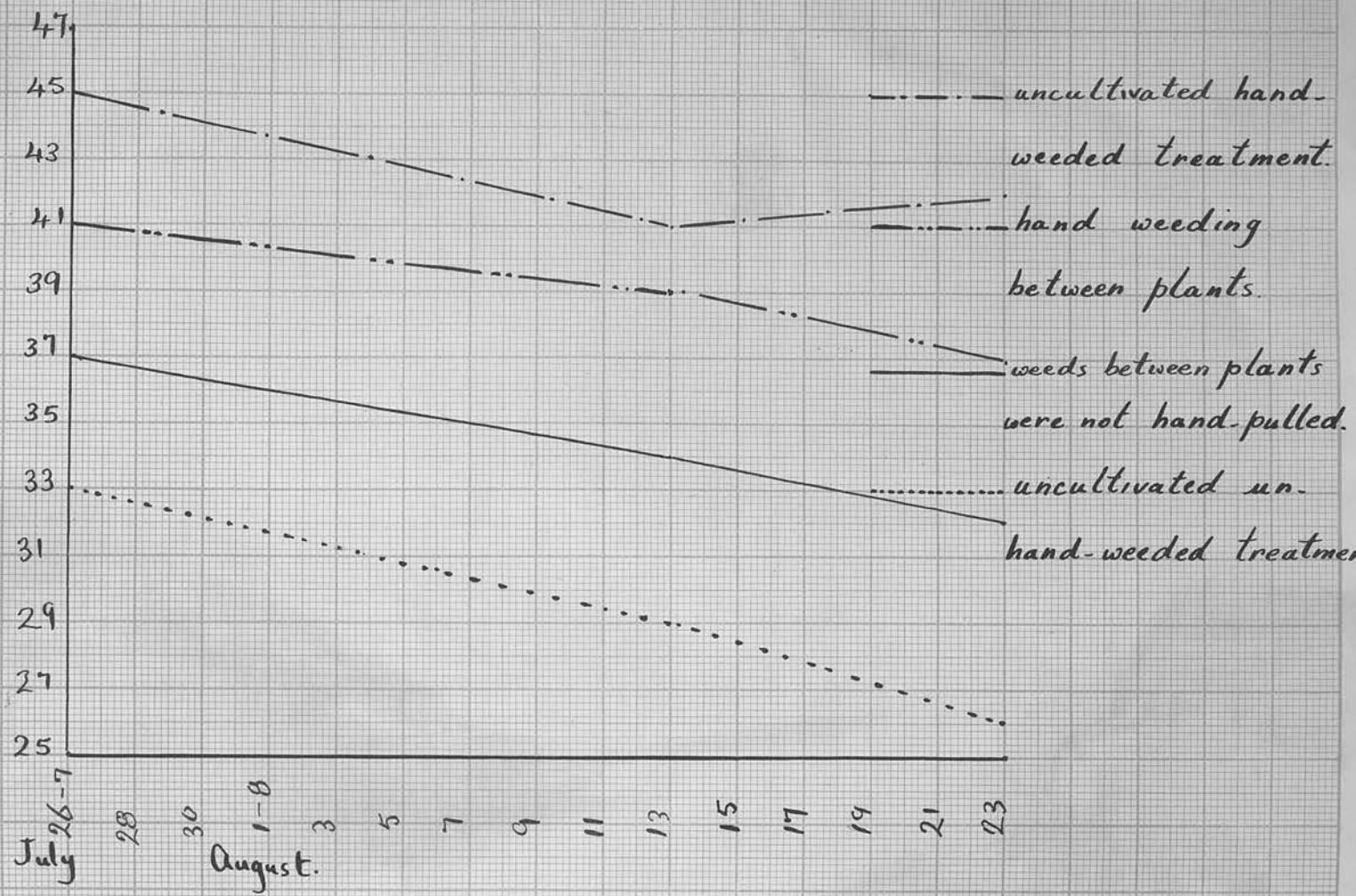
There was no difference of interaction of depth of planting with other cultural factors under study, width of cultivation, intensity of cultivation, etc., or with the combination of the two factors of cultural operations or more, except M.D.H. on 23rd August, 1951. (Table XIII).

Elimination of weeds between plants

Destroying of weeds between plants exerted its importance by the higher number of leaves per plant than in others where weeds between plants were allowed to grow (Table XIII, XIIId).

There was significant difference in the first and second counting and on the third counting in

Fig. IX. – Number of leaves per plant.



favour of pulling of weeds treatment.

This difference in leaf number could be due to the greater production of leaves, or the lower death rate or both of them in hand-weeded between plants than in others. This shows the importance of destroying weeds which compete with the crop for nitrogen, and result in reduction in leaf number (meristematic activity).

Fig. IX shows clearly the difference in leaf number between treatments of hand-weeding between plants and that of weeds allowed to grow between plants:

M.H. There is significant difference due to M.H. on the second and the third count. This could be split into W.H., I.H., etc.

W.H. There was no difference due to it. (Table XIIIb, f).

W.I.H. There was no difference due to it.

I.H. On the second count, the additional inter-row tillage did not result in an increase in leaf number per plant under hand and no hand pulling of weeds between plants. Elimination of weeds between plants resulted in an increase in number of leaves under the additional inter-row tillage, but the increase due to hand pulling under the two times of cultivation failed to reach the significant level (Table XIIIa). There was no difference due to I.H. on the last count (Table XIIIg).

$c_0h_0V.c_0h_1$ Plants of hand-weeded subplots had more leaves than the plants of weedy plots (Table XIIIc, e). This shows that weed competition resulted in a decrease

in leaf number and corollary in reduction in the plant photosynthetic system.

Fig. IX shows clearly the difference between the leaf number of c_0h_1 and c_0h_1 treatments.

M.D.H. There is difference due to this interaction on the last count (23rd August, 1951) at 5% level only.

Development of the Potato Tubers

From the observation, it is possible to draw mean curves giving a general idea of the successive stages in the potato tuber's progress for different treatment. The growth of tubers is presented graphically in Fig. X which shows the actual measurement of weight of tubers per plant.

The lines obtained by plotting the dry weight of tubers per plant directly against age, are in the form of an ascending curve indicating that the older the plant, the greater is the total weight of its tubers.

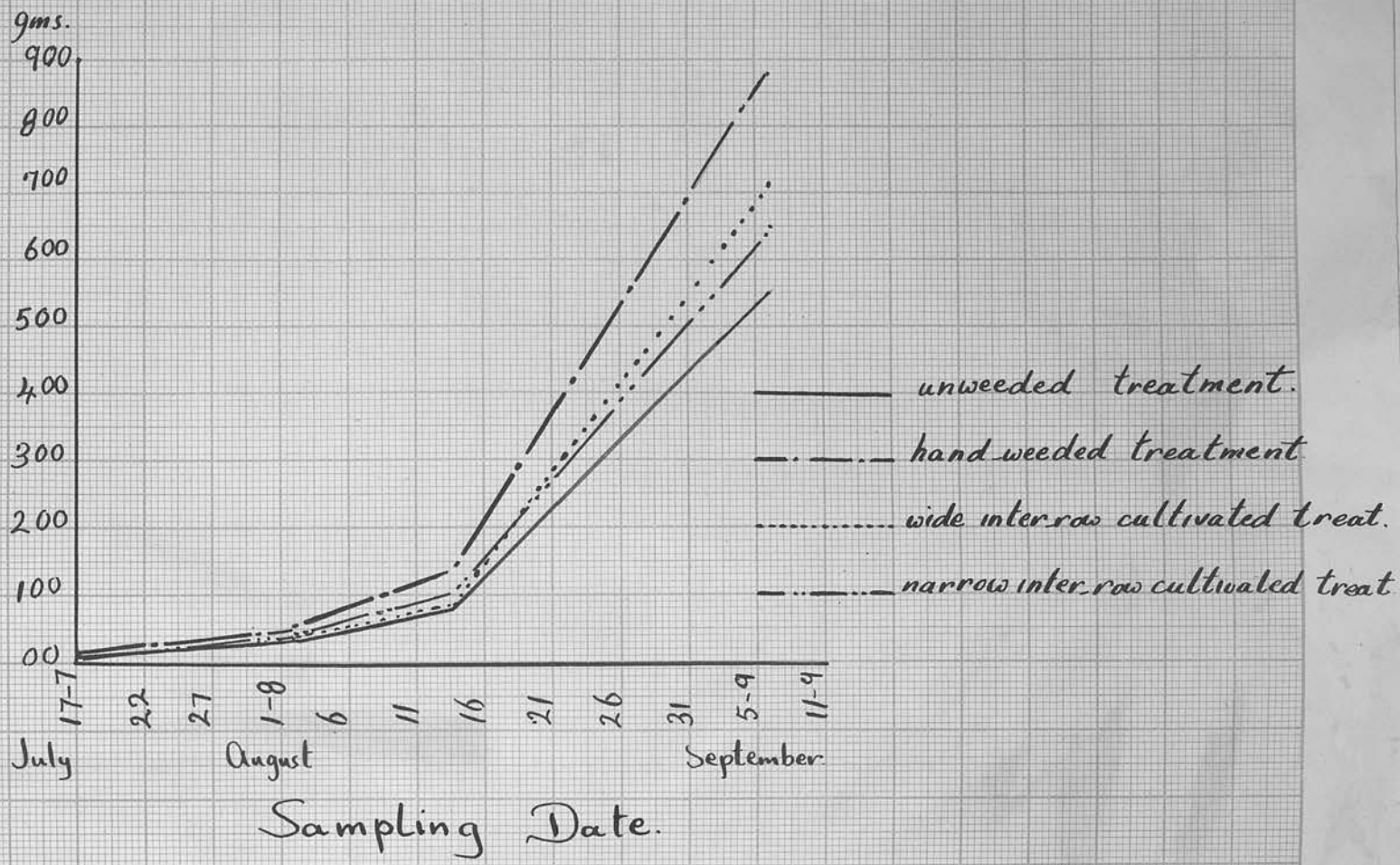
The difference between treatments, as shown in Fig. X, is the result of the difference in the amount of carbohydrates translocated to tubers.

The Composition of Potato Tubers
Table XIV

At harvest, the dry matter content of potato tubers (ware) was estimated for every sub-plot in the field (main experiment). The mean dry matter content in the first week after harvesting was 2.5%. Data show clearly that treatment has no significant effect on dry matter content%, moisture percentage of the tubers (ware). There was no significant difference between weedy and clean plots in dry matter percentage; clean plots gave higher yield and higher total amount of dry matter per acre, that is, large plants having higher total dry matter content. Nevertheless, cultural treatments appear to have no specific effect on dry matter %.

Fig. x. - Weight of tubers per plant.

(in gms.)



Physiological Ontogeny in Plants and its Relation to Cultural Treatments

The growth and development of a plant is a result of a number of ontogenetic processes. These processes are the directed and integrated metabolic reactions. The ontogenetic processes are classified according to Needham 1933 (31) as follows:-

1. Growth:

This includes the change in size and weight.

2. Changes in structure and organisation:

This includes differential morphological changes of all kinds and changes in the relative proportion of organs.

We can determine the drifts in the ratio of the dry weight of the various parts to that of the total plant.

3. Metabolism:

This includes the chemical reaction proceeding in the organism and resulting in the formation of new material.

The processes of the growth and changes in structure and organisation can be regarded as the expression of the metabolism. Interactions and inter-relations may occur among the processes of all the groups.

U.L.R. (Unit leaf rate) is a measure of metabolism.

L.W.R. (Leaf weight rate)" " " " morphological development.

Rate of accumulation " " " " the process of growth.

The rate of accumulation of the dry matter is the product of the leaf weight ratio and the unit leaf rate.

In this part another aspect of growth of the plant will be considered, namely the drifts of the dry matter in the organs of the plant. These effects indicate the relation of the growth of the plant to the environment and throw light on the mechanism of and inter-relations among ontogenetic processes. The measurements used are

Storage efficiency $\frac{\text{Tuber dry weight}}{\text{Total plant weight}}$

Assimilating efficiency $\frac{\text{Foliage dry weight}}{\text{Total plant weight}}$

Efficiency Index : Relative Growth Rate

This represents the rate at which fresh material is continuously added to the plant over a definite period. Blackman 1919 (6) efficiency index is a useful means of indicating the rate of growth at different periods of a plant. It is a measure of the efficiency of the plant in the production of new material. It is calculated by Blackman's formula (6) $W_1 = W_0 e^{rt}$

Efficiency index is not a constant value through the life growth of the plant, for it falls off after a time and ultimately reaches zero with cessation of growth. It equals minus sometimes due to cessation of growth and respiration. External conditions may vary and so modify its value.

West, Kidd and Briggs 1920 (7) have defined the relative growth rate as the weekly percentage rate at which dry weight increases. It equals efficiency index multiplied by 100 if the same units are used.

Method of Cultivation and Efficiency Index

The efficiency indices of plants under different cultural treatments are shown in Table XV. The difference in indices are shown graphically in Fig. XII.

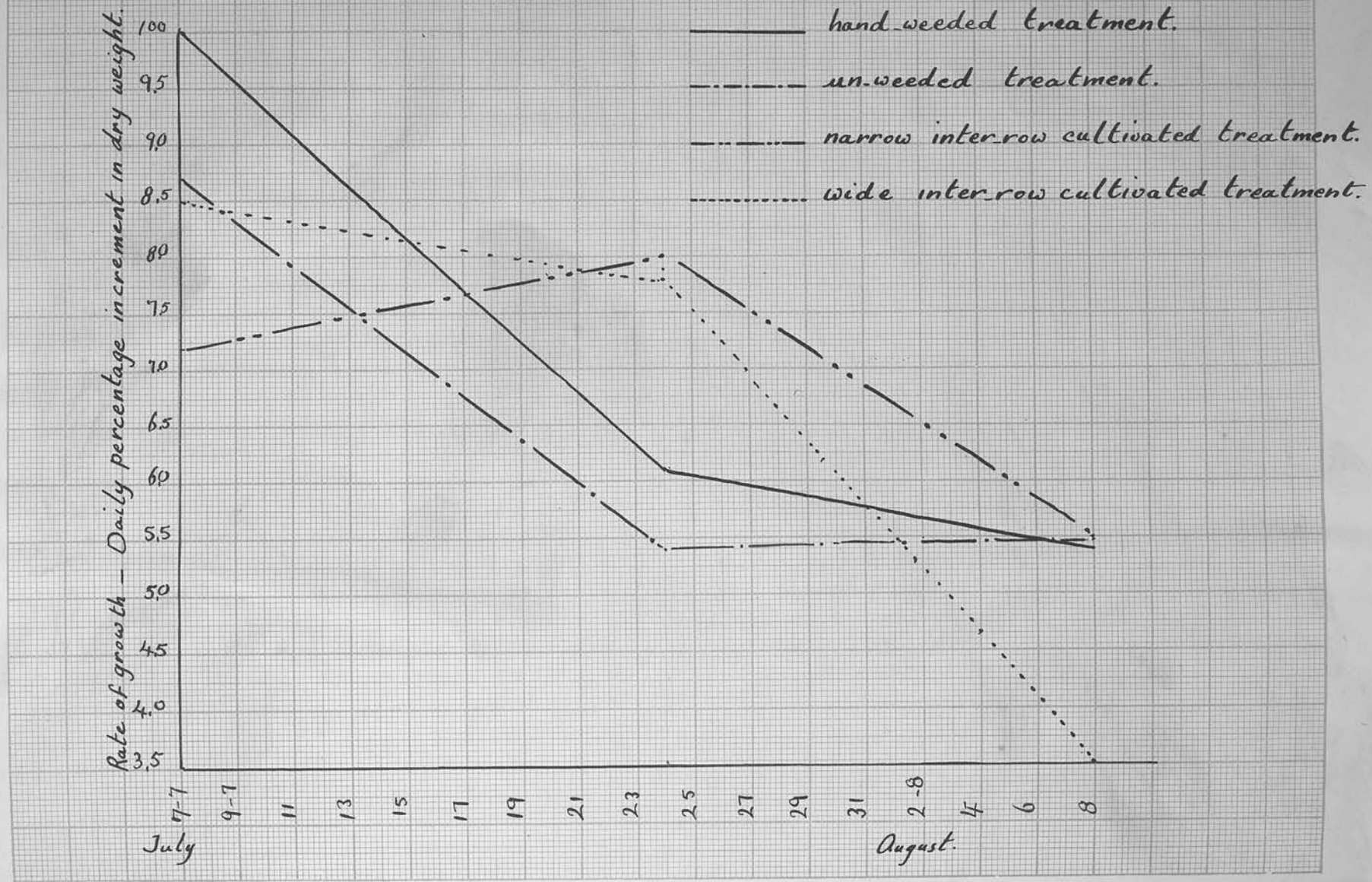
There is difference in efficiency index in favour of clean over dirty treatments. This difference is the result of different rate of assimilation between different treatments, due to competition of weeds with the crop. This difference in efficiency index leads to big difference in the final yield.

The graphs show that the efficiency index differs with different treatments; this shows clearly that the plant activity of different treatments differs. This indicates the response of the efficiency index of plant to external conditions.

Relation of Efficiency Index and the Age of the Plant

The efficiency index decreased as the plant became older. In Fig. X, efficiency indices are plotted against time for different periods for plants under different methods of cultural treatments. (Each sampling interval is plotted at the mid-point of the interval). An examination of the curve shows that during the growth period the indices fall.

Fig. X a. Efficiency index.



General Observation and a Preliminary Study on Plant Growth and the Distribution of Dry Matter in the Plant

The mechanism of the growth in the potato plant is so little understood that modification of the balance of growth which affect tuberisation and yield, cannot yet be properly estimated.

The general plan of growth applicable to potato is based primarily on the principle of competition for the available metabolites between the various organs of the plant.

Bald 1946 (2) stated that changes in the environment would produce characteristic changes in the partition of metabolites.

It is stated above that leaves dry weight per plant differ according to treatment. In other words, the photosynthetic system differs according to treatment. Therefore, the total amount of metabolites available for building the plant and the yield differs between different methods of cultivation, as a response to the external environmental conditions.

This section is devoted to the study of proportional distribution of metabolites between different organs.

The distribution of the dry matter has two main aspects:-

I. The change of the distribution of the dry matter with time.

II. The treatment effects in modifying the trends.

The treatment effects should usefully be studied with reference to (a) the ratio of the assimilating material

to the total plant body which in part controls the efficiency of the plant for the production of new material; (b) the proportion of tubers to the total dry matter of the plant or "storage efficiency" which determines the extent to which the effects on growth will lead to a commercial advantage.

The Storage Efficiency

In the early stages of plant development on 2nd August, 1951, there was significant difference between weedy plots and clean plots for storage efficiency in favour of weedy plots (Table XVI a). This shows that weed competition accelerated tuberisation and shortened the active foliage growth period. Tuberisation checks the formation and building of a big foliage size in early season.

At the end of growth period on 6th September, 1951, this difference in storage efficiency was narrowed and became insignificant (Table XVI b).

The storage efficiency increased with time as the foliage is restricted and food synthesised translocated to tubers.

The Assimilating Efficiency (Table XVII)

The assimilating efficiency decreased with time in the early growth, the plant devoting its activity to building its foliage; but then this trend is disturbed by checking foliage growth for tuberisation.

Data show that there was difference in favour of clean plots but this difference did not reach significant level.

General Observation on Growth

The general course of growth was that in the early stage of growth shoots emerged and extended leaves arose and expanded. There may be competition between roots and foliage at this period but the relative mass of roots was small. There was difference in the lateral extent of the root system between weedy and hand-weeded plot plants. Weeds restricted the development of the root system (stated above).

The second stage of growth opened with the beginning of the rapid growth of stolons. At this stage, available metabolites synthesised in leaves translocated to tubers (the underground growth) and the weight of foliage tended to be constant.

Assimilated food translocated to tubers where food is stored.

Of the total metabolites directed to build axillary growth above and below ground, shortly after the inception of the second stage of development, the proportion declined more or less rapidly as an increasing amount of metabolites moved to the tubers. At this stage the foliage had reached its maximum size.

The senescent stage was the last stage of growth. It extended from the time when the plant reached its maximum size until the haulm and roots were dead and the tubers were fully formed. The foliage was more or less at a static period when the formed metabolites were descending to the tubers and the quantity of foliage remained at a steady level. At the late part of the senescent stage, foliage was yellowing

and leaves were shedding. The weight of foliage decreased, as stated above.

The Yield

Since there are two different errors applicable to whole plots and subplots comparisons respectively, the calculation and the use of standard error applicable to the yield totals requires a little care.

In the method of cultivation, totals are totals of 8 whole plots and their standard error is therefore from the whole plot error mean square. In the depth of planting and method of cultivation, depth of planting interactions are totals of 20 and 4 whole plot respectively; and their standard error is therefore from the whole plot error mean square.

The hand-weeding are totals of 40 subplots and their standard error are therefore from the subplot error mean square.

The standard error of M.H., D.H., M.D.H. is from the subplot error mean square.

Efficiency of the experiment

It is immediately apparent that the whole plot comparisons are less precise than the subplot comparisons (Table XVIII). The ratio of the error variance being $\frac{416.78}{106.34} = 3.825 : 1$; if instead of assigning method depth combination to whole plots we had completely randomised all 20 combinations of M, H, D, there could only be a single error. The expected value of this error is shown in Table XVIII a.

This gives an error mean square of 253.39, so the precision of the method and depth comparisons would have been increased by complete randomisation in the ratio 416.78 : 253.39 = 1.64, while the precision of

hand-weeding effects and its interaction with method, depth would have been decreased in the ratio 106.34 : 253.39 = .41.

Because of difficulty of the work in the field the method and depth combination treatments were put on the whole plots and the hand-weeding on the subplot to facilitate working of the tractor.

The Gross Yield

Effect of weeds on the yield

The clean hand-weeded subplots gave heavier yield than subplots where weeds were allowed to grow. In the dirty subplots the yield was .64 $(\frac{c_0h_0}{c_0h_1})$ of that of the clean subplots where weeds were kept down by hand pulling. This shows how very much the weeds depressed the potato yield. This confirms farmers' beliefs as well as the results of workers in all parts of the world on potato crops and on other crops (Lombard 1936 (24), Russell 1949 (40).

The conclusion is that weeds can set back the potato growth very severely.

From the experiment, it could not be determined whether this depression of yield was due to the action of weeds

(i) in taking up soil moisture,

(ii) in taking up mineral nutrients,

(iii) in shading, thus checking synthesis of carbohydrates, or

(iv) in making the soil toxic.

The crop showed a very considerable sensitivity to weed competition. This indicates that it is of

great importance to maintain the crop in a weed free condition.

The effect of soil mulch on the yield

This section shows whether the main object of inter-row cultivation of the potato crop was weed suppression or the net result of inter-row fine tilth and destruction of surface feeding roots, which are produced as a by-product of this inter-row cultivation, had any beneficial result in the growth of the crop.

The comparison made in here is in one the weeds were removed by hand pulling without any appreciable mulch being produced. In the second, the weeds were destroyed by inter-row tillage, thus maintaining the loose fine tilth and eliminating the weeds between plants by hand pulling, so that the difference between these two treatments is solely due to soil mulch and surface-feeding roots destruction.

The data show that the/zero cultivation treatments where weeds were removed by hand, pulling was better than the inter-row cultivated subplots. The latter was much better than the control (c_0h_0).

This shows that there is no benefit of inter-row tillage apart from killing weeds, under this experiment; on the contrary, the injurious effect of destroying the surface feeding-roots outweighed its beneficial effect of maintaining a loose mulch, apart from destroying weeds. (Table XVIII f)

The difference between the uncultivated hand-weeded treatment and the narrow cultivated hand-weeded treatment in favour of the former did not reach the significant level (Table XVIII g). Not much harm was done to the root system under narrow inter-row cultivation.

Depth of planting

There is no significant difference due to depth of planting (Table XVIII). The difference in the means, both of yield and of percentage wares, were not only within the marginal error but also negligible from the viewpoint of the practical grower. The shallow planted tubers gave more yield than the deep-planted treatments; the difference of 2.34% in yield between shallow and deep-planted treatments was not statistically established and may be due to chance.

The treatment should be done on a variety of seasons and on widely different depths, to see if there is any real difference due to the depth of planting.

D.W. Depth of planting, width of inter-row cultivation interaction.

D.I. Depth of planting, intensity of inter-row cultivation interaction.

D.H. Depth of planting, hand-weeding interaction.

All these interactions of depth of planting with width, intensity, and hand-weeding between plants, did not reach the (5%) significant level.

Hand-Weeding (Table XVIII b)

There was a great difference due to eliminating weeds between plants after inter-row cultivation and no hand-weeding, in favour of hand-weeding. Pulling of weeds between plants resulted in more leaves per plant and, therefore, the photosynthetic system of plants was greater than plants of plots where weeds between plants were allowed to grow (stated above).

This difference in yield is due to the competition of weeds with the crop for nutrients, moisture, light. This experiment does not show which is the limiting factor, although by the visual methods of diagnosis in the field leaf number, the nitrogen deficiency was highly manifested in weedy plots. The outstanding clear symptom of this was the restricted growth of the top, and leaves were small, pale-yellowish green colour in the early stages of growth and later they developed coloured tints of yellowish tinting, began on the older foliage and proceeded towards the younger leaves.

During the growth season, plants did not show any symptom of water deficiency.

Hand hoeing between plants is still very important as there is no other tillage method to control weeds between plants on ridges by machine. In the experiment, hand hoeing was replaced by hand weeding to eliminate weeds between plants which could not be eliminated by cultivation.

Effect of width of cultivation on yield

The significant difference due to the main effect of width of inter-row tillage failed to express itself (Table XVIII d). This will be shown clearly below as due to the interaction of width of cultivation with weeding and no eliminating of weeds between plants, and to the interaction of width and the intensity of inter-row tillage.

Effect of intensity of cultivation on yield

The additional third inter-row tillage exerted its importance by the increase in yield (Table XVIIIe). The additional third inter-row tillage resulted in an increase of weed destruction and root cutting. Its beneficial effects in destroying weeds outweighed the harm it did in other respects.

Its harm effect was at its minimum. The cultivation was followed immediately by rain. The high availability of soil moisture helped the plant to restore the disturbed balance of water.

The Control

Zero cultivation, without destroying weeds by any means, yielded less crop than any cultivated treatment.

Zero cultivation gave the best yield when the subplots were kept clean by hand-pulling of weeds. Plants grew freely with neither competition of weeds nor checking of the plants due to the cutting of roots. It gave better yield than cultivated hand-weeded treatment(Table XVIII f). The method of keeping land clean without doing harm to the roots or with the minimum harm, is the one recommended.

W.I.: Width of cultivation x Intensity of cultivation interaction (Table XVIII e)

The additional third inter-row cultivation increased the yield under narrow inter-row tillage by 7.0%. This held true under wide inter-row tillage and the increase was 6.2%. This beneficial effect was due to the destruction of weeds and so the competition of weeds with the crop was checked.

The cutting of roots resulting from this additional cultivation did not offset or outweigh the beneficial effect of eliminating weeds.

There was no significant difference between wide and narrow inter-row tillage whether done twice or three times.

I.H. : Intensity x Hand-weeding interaction (Table XIIIc)

Elimination of weeds between plants by hand-weeding increased the yield under both the two times and three times of inter-row tillage. The increase was 21% and 13.1% under two times and three times respectively. Under no hand-weeding, the additional third inter-row tillage benefited the crop, but the beneficial effect under cutting weeds between plants failed to reach the significant level. This made the increase percent due to hand-weeding under three times of cultivation less than at two times. although the total yield of hand-weeded subplots at three times of inter-row tillage was more than at two times.

Killing weeds which cannot be reached by mechanical means is very important. This eliminated the competition of weeds, which results in robbing the crop of food, moisture and light.

The additional inter-row tillage increased the yield when weeds between plants were not eliminated. Thus the additional inter-row tillage expressed its importance under this condition. The beneficial effect outweighed its expected harm effect of cutting roots, as roots at that time fill the furrow

The expected harm effect of the additional

inter-row tillage is a result of the disturbance of water balance in the plant, which was at its minimum. This was because the cultivation was just followed by rain. The more abundant soil moisture available for absorption compensated the smaller amount of water absorbed by a smaller root system. The need for a big root system was not urgent because this cut root system could manage as the absorbing area per root would be increased owing to the abundant moisture in soil.

When weeds between plants were eliminated by hand-pulling, the increase due to the additional third inter-row tillage failed to reach the significant level. This additional cultivation was of no use when the land was kept clean. It could be of much harm under dry conditions, as the plant would suffer the disturbance of water balance.

The increase per cent of the third inter-row tillage over two times at no hand-weeding, was 11.1%, and at weeding between plants 2.8%, although the total yield of hand-weeded subplots under three times of cultivation was much more than at no hand-weeding. This is because at low intensity of two times, the hand-weeded subplots yield was high.

W.H. : Width of cultivation and hand-weeding interaction (Table XVIII d)

Elimination of weeds between plants increased the yield. This holds good under both wide and narrow inter-row tillage.

The gain due to hand-weeding between plants was

21.7%, 12.2% under narrow and wide inter-row tillage respectively. This again shows the importance of killing weeds not eliminated by cultivation. This difference in response was due to the higher yield of wide inter-row tillage under h_0 or better response of yield under this condition due to more destruction of weeds than at narrow inter-row tillage. Under hand-weeding, the crop at narrow inter-row tillage was better than at wide inter-row tillage, due to the destruction of more roots at the latter.

The wide inter-row tillage increased the yield when weeds were not eliminated between plants. The destruction of more weeds due to wide inter-row tillage outweighed the harm of the destruction of more roots. This was expressed by a significant difference in favour of wide inter-row tillage, when weeds were not eliminated between plants.

Under h_1, the significant difference was in favour of narrow inter-row tillage. This increase was solely due to the smaller destruction of roots, as the weeds not killed by cultivation were eliminated by hand-weeding. Under clean cultivation, the importance of cutting roots came to materialise.

W.I.H. : There is no significant difference due to this second-order interaction.

Tuber Size

Effect of cultural treatments on the size of tubers (Tables XVIV, XX a, XX b)

Throughout the paper, the yield data refer to all the tubers gathered up; ware, that is the tubers saleable for food, seed and chat. The ware per cent of every subplot was estimated and this was transformed into grades $p = \sin^2 \phi$ (Fisher and Yates 1949). The analysis (Tables XX) shows that there is significant difference due to the following treatments:- (i) hand-weeding; (ii) M.H.; (iii) M.D.H. The analysis of variance of seed per cent. (Table XVIV) confirms this result.

Hand-weeding

The data show that the action of hand-weeding on tuber size was considerable and statistically significant. It is in the same direction as on yield.

Hand-weeding destroyed weeds between plants and large foliage synthesised a big amount of food; therefore there was more chance for tubers to grow and reach the ware size.

c_0H

Hand-weeding of uncultivated subplots had bigger size and more percentage of ware than unhand-weeded uncultivated subplots. This goes in the same direction as the effect of hand-weeding on yield. Weeds compete with the crop and restrict the amount of metabolites available for the sizing of tubers.

W.H. : Width of cultivation, hand-weeding interaction

The difference of ware size per cent did not reach the significant level.

I.H. : Intensity of inter-row tillage and hand-weeding interaction

Under two times of cultivation, elimination of weeds between plants helped to increase the ware size per cent and a decrease in seed size per cent. The increase in ware size per cent goes in the same direction as the effect of hand-weeding on yield.

Under three times of cultivation, the difference in ware or seed size between hand and no hand-weeding between plants did not reach the significant level.

Under no hand-weeding, the additional third inter-row tillage increased ware percentage. This goes in the same direction as the effect on yield.

Under hand-weeding, the difference in ware percentage was in favour of two t imes of cultivation. This is in the opposite direction with the yield. No explanation for this could be detected.

Efficiency of the Experiment
(Seed per cent.)

It is clear that the whole plot comparisons are less precise than the subplot comparisons (Table XVIV), the ratio of the error variances being 16.02 : 4.59 = 3.2 : 1. If we had completely randomised all 20 combinations of depth of planting, method of cultivation and hand-weeding between plants, there would only be a single error. The error of the experiment was calculated with complete randomisation (Table XVIV a).

The complete randomisation gives an error mean square of 10.004, so that the precision of the hand-weeding, M.H., D.H. and M.D.H. would have been decreased by complete randomisation in the ratio of 4.59 : 10.004, while the precision of the method of cultivation, depth of planting and their interactions would have been increased in the ratio 16.02 : 10.004.

P A R T II

1952

I N T R O D U C T I O N

Width of inter-row cultivation is very important. Wide inter-row cultivation destroys more weeds than narrow inter-row cultivation and the weeds left to be hand-hoed are fewer. But if wide inter-row cultivation is done late in the season, it causes much harm, destroying more roots, because at this time the roots of the plant fill the furrows. Two widths of inter-row cultivation, wide and narrow, were under study last year. Another factor of wide inter-row cultivation in the early growing season, followed by narrow inter-row cultivation in the second and the second third cultivation, is under study this year.

The time of weed elimination is introduced as a factor in this year's study to see to what extent weeds compete with the crop from the start of the growth period.

In this year there are:-

A sub-experiment to show the effect of weed competition and root pruning on the development and growth of the potato plant.

A small yield experiment of 2 x 2 block randomised system to show the effect of two depths of planting with two times of elimination of weeds and their interaction.

Another big yield experiment of split plot design to study the effect of many factors.

The experiments were conducted in the same field

as last year's experiment at Dryden Mains Farm, Steading Field East.

The soil of the experiment is chocolate in appearance with a yellowish sub-soil. The soil surface is gravelly sandy loam, pH 6.2., potash medium and phosphate high. The area was cropped with swedes ploughed in winter and harrowed in Spring, ridged on 21st April, 1952, and fertilizer of 10 cwt. potato crop main fertilizer was applied. Planting and splitting ridges of main and sub-experiment were on 22nd April, 1952. The 2 x 2 experiment was planted on 22nd April, 1952, and depth of planting was maintained by dibbling.

Red skin variety was planted in this year's experiments.

The following weeds were associated with the field in which the experiment was conducted:-

	Scientific Names	Local Names of Weeds
1.	Brassica Sinapsis	Charlock
2.	Stellaria media	Chickweed
3.	Dactylis glomerata	Grass, Cocksfoot
4.	Agrapyron caninum	Bearded couch grass
5.	Poa annua	Grass Annual Meadow
6.	Tanacetum vulgare	Tansy
7.	Plantago major	Plantuin
8.	Cnicus arvensis	Thistle

2 x 2 Experiment

This experiment is devoted to study the combinations of the following two factors:-

(1) Depth of planting (D) (2) Time of weeding (T).

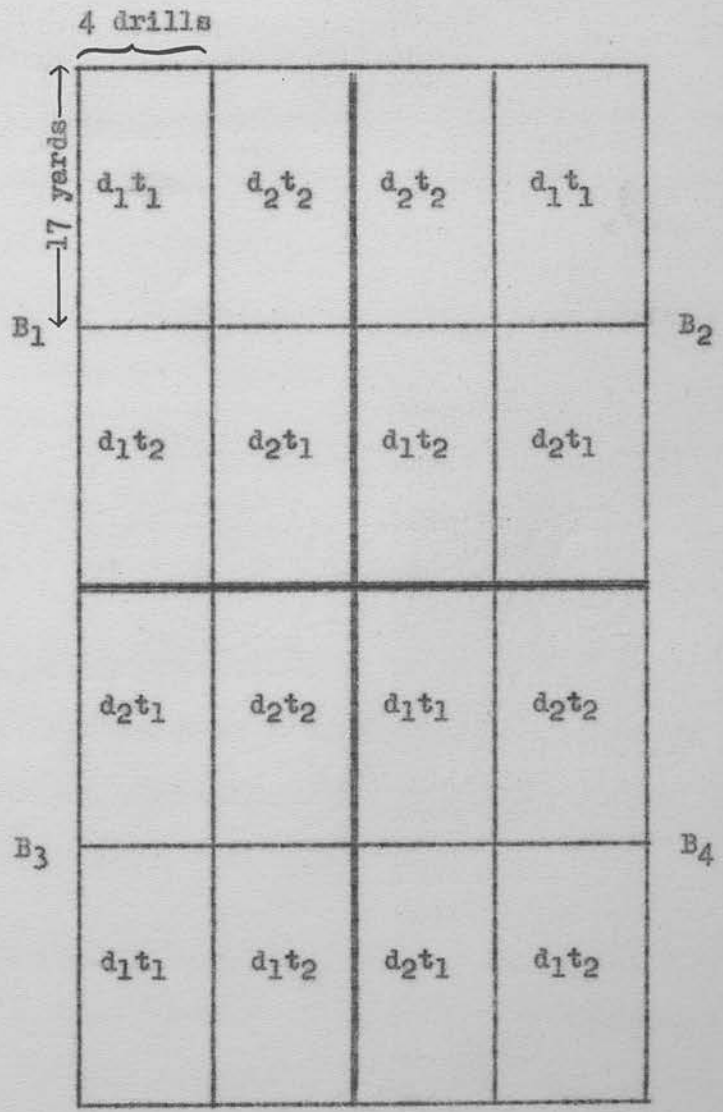
(1) Depth of planting - There were two levels:

a) shallow planting - plants planted 3" deep from the top of the ridge.

Plate VI.

THE LAY-OUT

2 x 2 Experiment



d_1 depth of planting is 7" from the top of the ridge

d_2 " " 3" " "

t_1 first weeding was on 3rd June

t_2 " " " " 25th "

B replicate

(iii) The height of plants under leaf-number observation.

(iv) The number of flowered plants were recorded at two days' interval during flowering period.

(v) The yield and yield grades, that is ware, seed, chat.

Statistical Analysis

The progressive data on number of leaves and height of plants were graphically represented. The other information was tabulated. The difference between treatments is considered significant whenever it exceeds S.E $\sqrt{2}$ x t

In tables of results significant treatments at 1% level were marked by two asterisks ** and those significant at 5% level by one asterisk *.

The Sampling Procedure

Twelve plants were selected from 78 plants after allowing for guard rows and edge plants. The size of the sample is 15.3%.

Effect of Depth of Planting on Rate of Emergence

The plants were counted as up when they started to unfold their first leaves. Counts of plants were recorded at two days' interval from 20th June to 7th July, 1952.

The germination rate index of every plot of the experiment was constructed from the mean fraction of finally emerging plants taken over the several times.

The rate index was subjected to the proper statistical analysis. There was a highly significant difference (Table XXI) due to depth of planting in favour of shallow planting. This confirms last Year's result and Hardenburg's result 1935.

Table XXII shows the per cent. number of plants come-up by stated dates, and Table XXIII shows the per cent. of come-up at different periods.

After about 32 days (Table XXII) from planting, approximately 13 per cent. more plants had emerged from the shallow planting than from the deep planting.

The coming up of the plants covered about twenty days. They did not come up simultaneously owing to the difference in edaphic factors between different parts of the field and to the state of growth of tubers at planting time.

In order to gain an indication of the extent of delay, the median date of come-up was calculated. That on which 50% of the stand was complete was defined as the median date of come-up. Date of come-up was 24th and 25th May, 1952, for shallow and deep planting respectively.

The conclusion is that the shallow planting hastened the emergence of plants.

Graphical Representation of Data

The frequency distribution for coming-up of plants are shown in Figs. XI, XII. In Fig.XI, the cumulative percentage frequencies are represented, that is, the per cent. number of plants which have

Fig. XI _Percentage of plants which have emerged by stated dates.

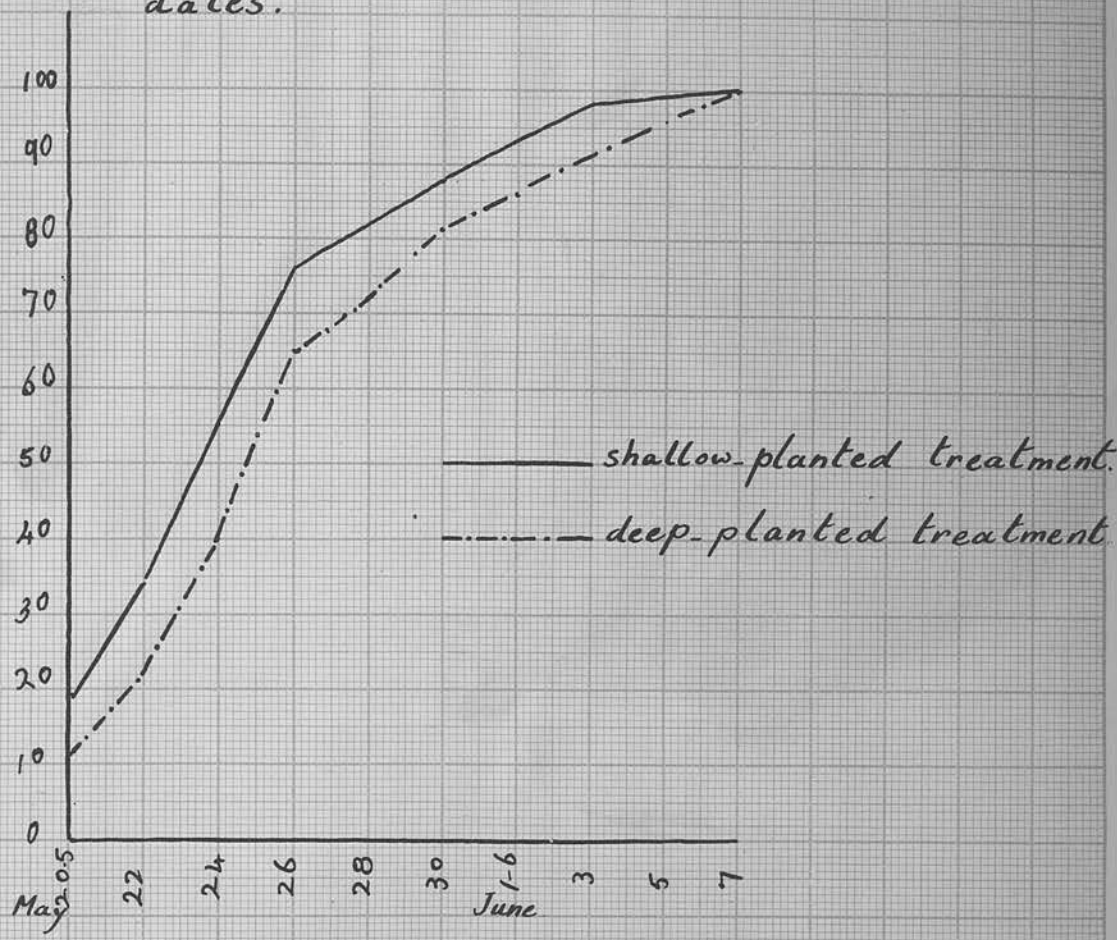
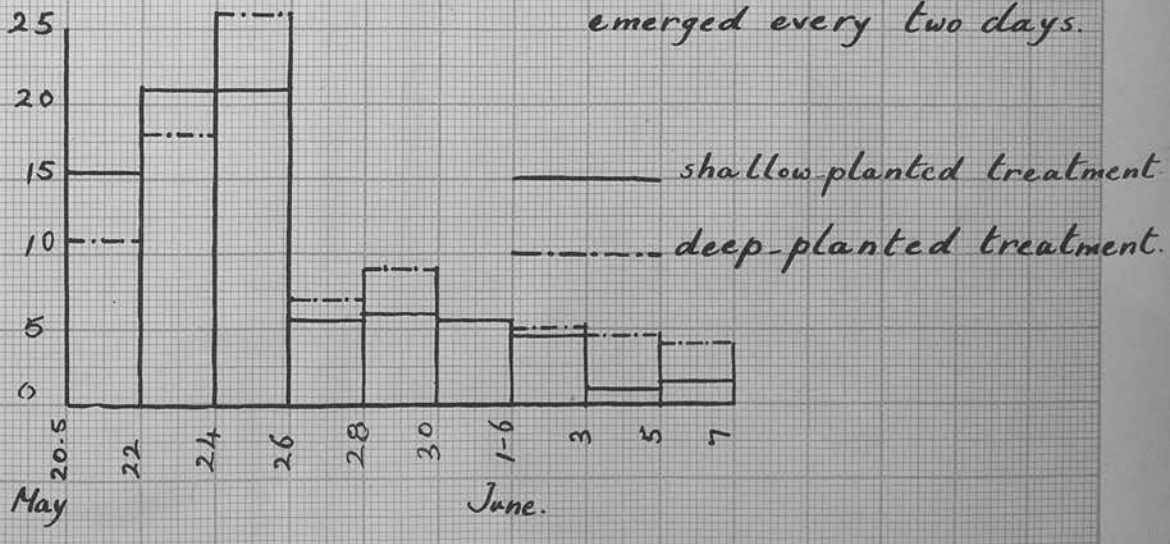


Fig. XII. _Frequency distribution of time of emergence of plants (percentage frequencies). Percentage of plants which emerged every two days.



come up by given dates for deep and shallow planting. The figures show that the difference was wide at the start and the two lines became nearer and nearer with time.

Fig. XII represents the actual two days in cumulative percentage frequencies.

FLOWERING

The number of plants coming to flower were recorded at two days' interval.

To study the effect of the cultural treatments on the date of flowering, a flowering rate index was calculated on basis of germination rate index of Bartlett 1937. for every plot of the experiment. The figures were then subjected to the proper statistical analysis.

The rate index is equivalent to the mean date of flowering. It summarises the experimental readings in a single value.

There is a significant difference in favour of shallow planting (Table XXIV). The shallow-planted plants came to flower earlier than the deep-planted plants.

Plants coming to flower on successive dates were expressed as percentage of the total number of plants coming to flower (Table XXIV a). Table XXIV b shows the percentage of plants coming to flower under shallow and deep planting at different intervals.

The frequency distribution of flowering is graphically represented in Fig. XIII, XIV.

Fig. XIII. _Percentage of plants which have flowered by stated dates.

Fig. XIV. _Frequency distribution of time of flowering (percentage frequencies). Percentage of plants which flowered every two days.

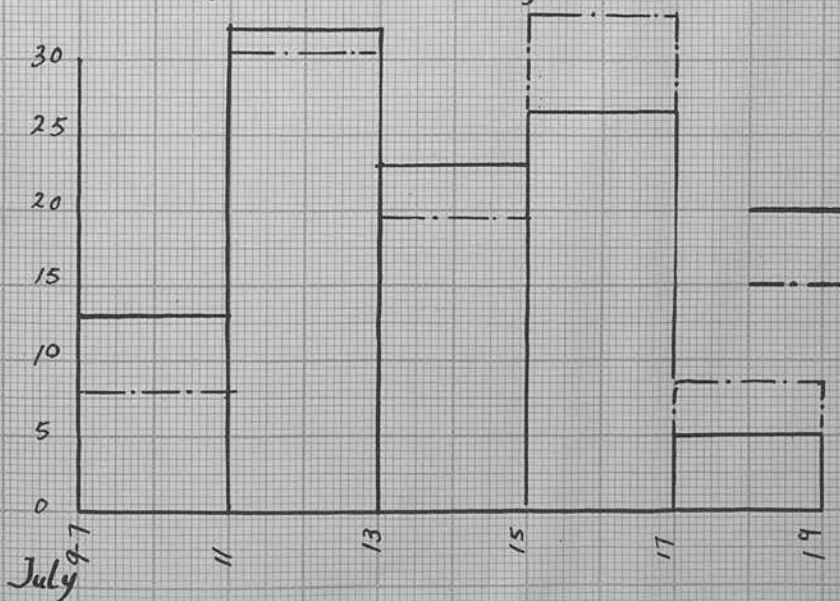


Fig. XIII represents the per cent. number of plants which have flowered by stated dates. Fig. XIV represents the frequency distribution of flowering.

NUMBER OF LEAVES

Twelve plants were selected at random from every plot, six plants per row excluding the guard rows and edge plants.

The number of leaves was recorded five times during the growing season on 12th, 24th, 30th June and 9th, 21st July.

The number of leaves per plant under different cultural conditions was plotted against time. The curve shows a trend of increasing the number of leaves during the growth period. Fig. XV.

On 12th June, 1952, there was significant difference in leaf number in favour of shallow planting. This held true during all the counting times, except on 24th June (Table XXV).

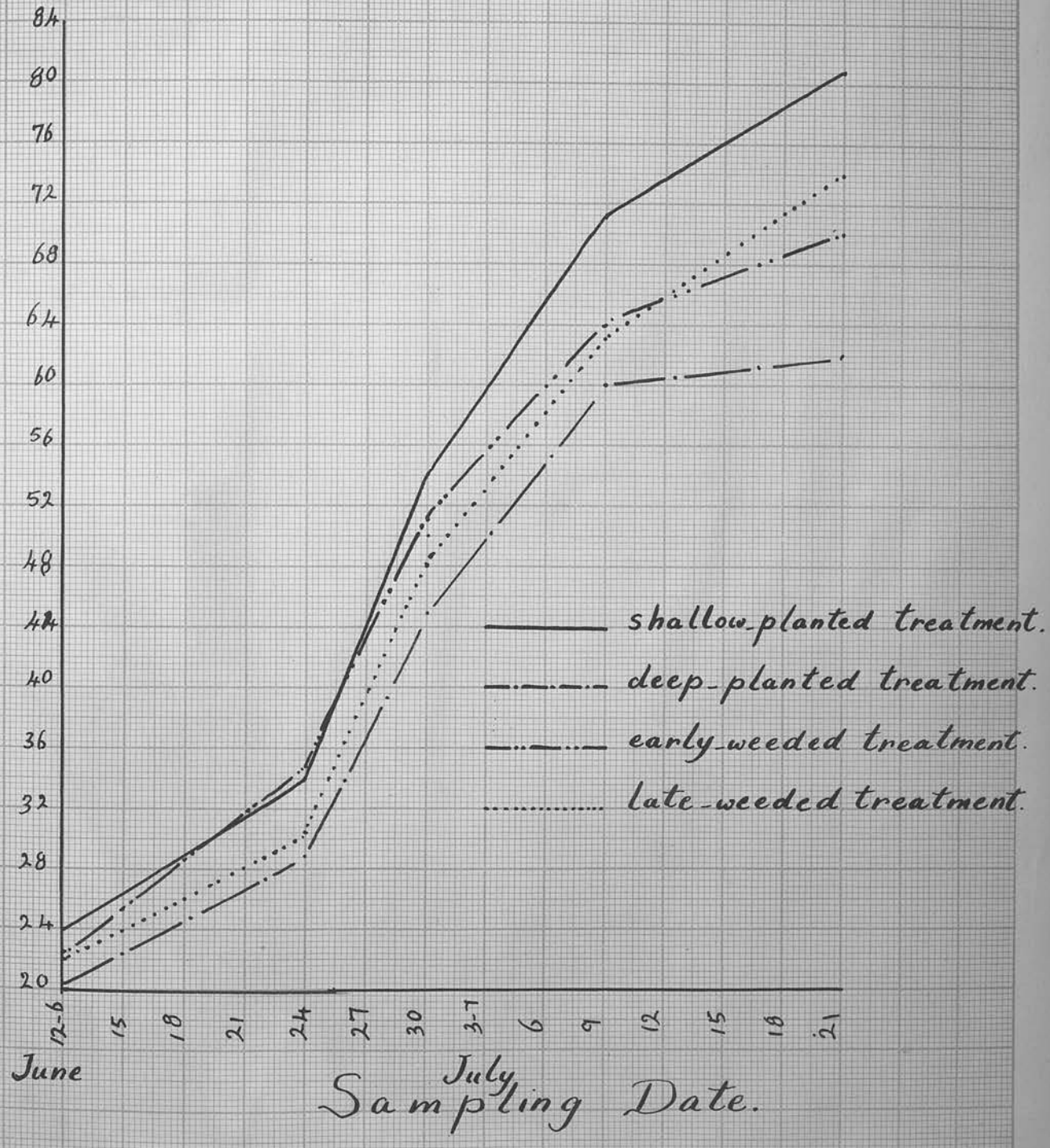
There was difference in leaf number per plant in favour of early weeding over late weeding. This held true in first, second, third and fourth counting. On the fifth counting this was changed and the difference was in favour of late weeding. The difference in leaf number between early and late weeding never reached the significant level in all counting.

There was no significant difference due to treatment and time of elimination of weeds interaction.

The conclusion is that the shallow planting resulted in a larger number of leaves per plant.

Fig. XV.

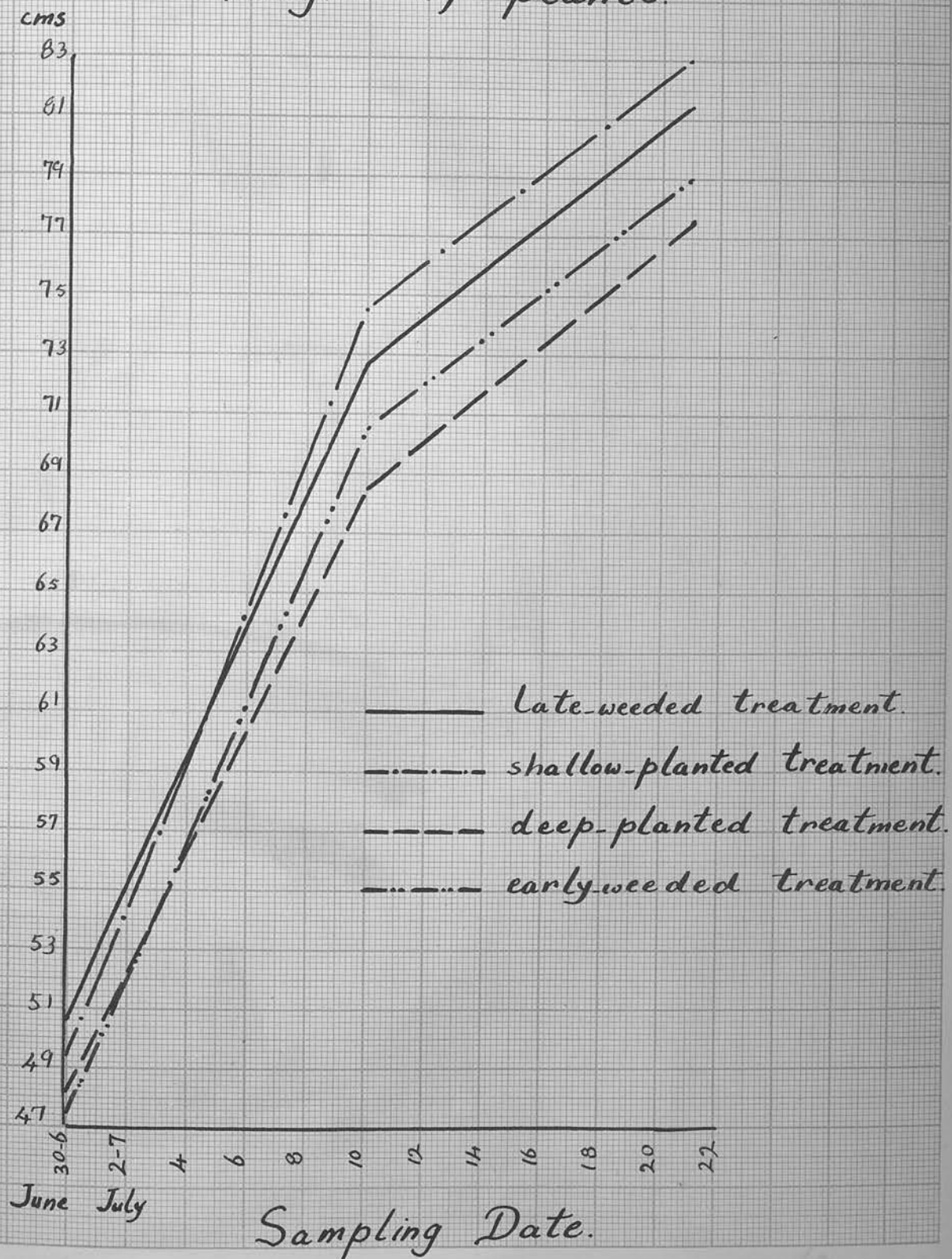
Number of leaves per plant.



Sampling Date.

Fig. XVI.

Height of plants.



2 x 2 EXPERIMENT

Total Yield

Table XXVI shows that there is no significant difference due to depth of planting, time of weeding and depth of planting, time of weeding interaction.

The mean yield in tons per acre for the different treatments under study is shown in Table XXVII. The mean yield in tons per acre was 17.6 and 16.3 for shallow and deep planting respectively. The difference in favour of shallow planting just failed to reach the significant level.

Elimination of weeds early in the growth season gives the plants a better chance to grow without competition of weeds than when weeds are destroyed late in the growth season. Early cleaning treatments gave better yield than late cleaning treatments by 104.8%. The mean yields in tons per acre for early and late weeding were 17.4 and 16.6 respectively. This difference in total yield in favour of early weeding did not reach the significant level.

Size of Tubers

All potatoes were lifted by hand and passed over 2" riddle. Potatoes were sorted into three grades:-

(i) Ware more than 2"
(ii) Seed 2" - 1¼"
(iii) Chat less than 1¼"

Ware and seed percentages were transformed to degrees (Fisher and Yates 1949 (14). These degrees were subjected to the proper statistical analysis.

The analysis of variance (Table XXVII) shows that

there is no significant difference due to any treatmenteither in ware % or in seed %. The mean ware %, seed % and chat % of different treatments are shown in Table XXVII.

These results of total yield, ware per cent and seed per cent. are not decisive. The experiment should be repeated on different soils and different seasons before any conclusion is drawn.

THE SUB-EXPERIMENT
1952

To study the effect of weeds and pruning of roots on the growth and development of the potato plants, a sub-experiment was conducted. There were three treatments under this study.

1. Pruning of roots 4 inches apart from the plant to a depth of 4 inches, three times at about weekly intervals after emergence.
2. Weeds were allowed to grow and to compete with the crop.
3. Weeds were pulled by hand.

In the case of pruning of root treatment, weeds were hand-pulled, so that the difference between this treatment and the clean hand-weeded treatment lies solely in pruning of roots.

The experiment is of a simple block randomised system (Plate VII) There were three treatments, and six replicates. Every plot consisted of 4 drills, 27 inches apart and 60 feet in length. On 21st April, 1952, seeds were planted 14 inches apart.

Experimental treatments

Weeds were hand-pulled three times on 3rd June, 11th June, and 26th June: roots were pruned on these same three days.

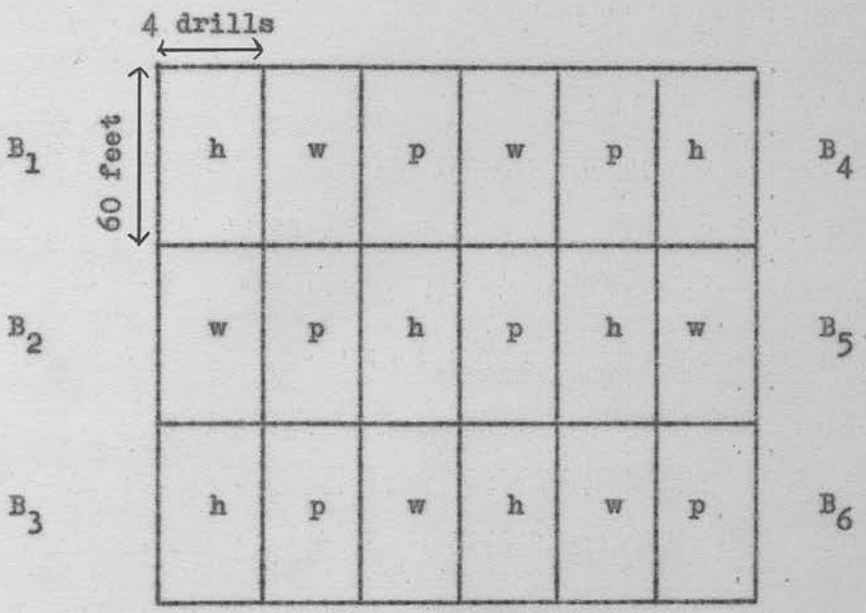
Plant growth studies

The following data were recorded from the sub-experiment.

(i) The number of leaves per plant were counted on 16th June, 1st July, 14th July and 28th July.

Plate VII.

THE SUB-EXPERIMENT



B stands for Replicate

h weeds were pulled by hand

w weeds were allowed to grow and to compete with the crop

p roots were pruned 4" apart from the plant to a depth of 4"

(ii) The dry weight of the plant and its different parts, that is, leaves, stems, tubers, roots and stolens. (Sampling dates were on 16th June, 1st, 14th and 28th July.

(iii) The lateral extent and depth of the root system were recorded on 16th June, 1st and 14th July.

(iv) The dry matter per cent. of the tubers.

(v) The number of tubers per plant.

(vi) The branching of the primary roots.

(vii) The soil moisture was estimated on 7th July.

Derived data

From the primary data, the following derived data were studied.

1. Relative growth rate
2. Relative leaf growth rate
3. Net assimilation rate.

The sampling procedure

Four plants were selected at random every time from every plot; two plants from each row after allowing for guard rows and edge plants. Plants next to the plant sampled on the previous occasion were excluded at the next sampling time.

Every plant was separated into its organs, stems, leaves, tubers and stolons and roots together.

Plants and plant parts were dried in an electric oven at 105° for 24 hours, and dry matter estimated.

The statistical analysis and the method of the presentation of data

The methods of statistical analysis have not

been described in detail. Reference may be made to Paterson's statistical book (32).

The notation of the level of treatment is by w, h, p for weedy treatment, hand-weeded treatment and pruned root treatment respectively.

The progressive data on developmental studies, weight of leaves, number of leaves, etc., were subjected to a proper statistical analysis, and they are graphically represented. Information was recorded in the form of a two-way table on the basis of the statistical analysis with the error appropriate to the standard error in most cases.

Difference more than t S.E $\sqrt{2}$ is considered significant. Significant results at 5% were marked with one asterisk * and at 1% with two asterisks **. As regards treatment or time of sampling arrangement, treatment and time will be on the same line when the difference between them failed to reach the significant level.

Number of leaves per plant

Table XXVIII shows the analysis of variance of the number of leaves per plant. There is difference due to (i) treatment, (ii) time, (iii) and treatment x time interaction. Next one has to ask where these differences lie.

Time (Table XXVIII a)

The number of leaves per plant in ascending order is:-

	Mean number of leaves per plant
t_1 (16th June)	26.8
t_2 (1st July)	43.6
t_3 (14th July)	58.9
t_4 (26th July)	65.4

This simply means that the number of leaves increased with time.

Treatment (Table XXVIIIa)

The number of leaves per plant under different treatments is arranged in ascending order as follows:-

	Mean number of leaves per plant
w (weedy treatment)	42.4
p (pruned root treatment)	47.6
h (hand-weeded treatment)	56.1

The difference between weedy treatment and hand-weeded treatment is a result of weed competition with the crop. Weeds resulted in a reduction in number of leaves per plant, or in other words, reduced the meristemmatic activity of the plant.

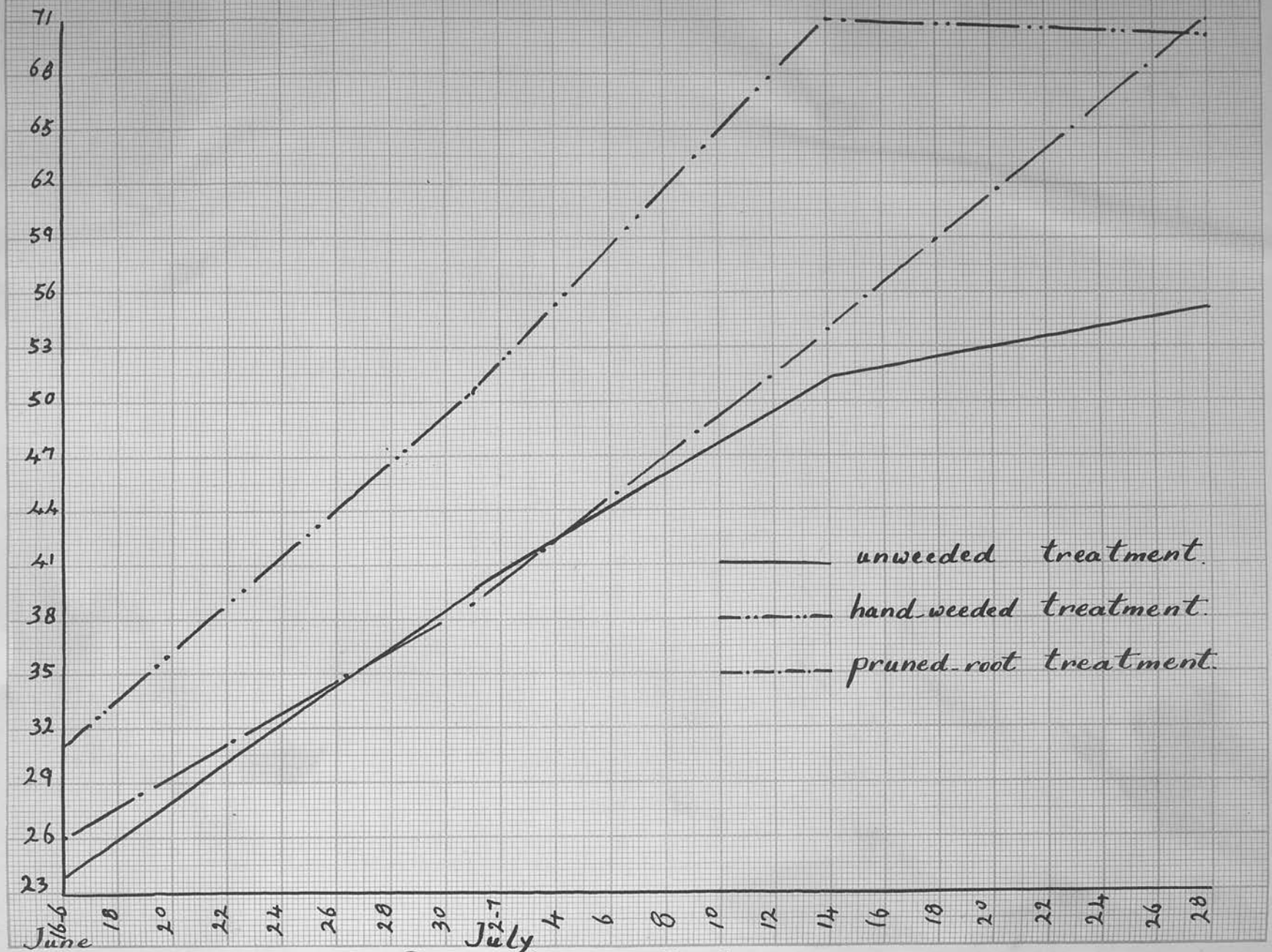
Pruning disturbed the balanced system between roots and foliage. The pruned plants had more leaves than the plants which suffered the weed competition. The check of growth due to pruning was less severe than the effect of weed competition on the crop.

Treatment x Time Interaction (Table XXVIIIa)

This means that the number of leaves per plant under different cultural treatments varies with the time.

The number of leaves per plant in the treatments increased with time. The difference between t_3 (14th July) and t_4 (28th July) in favour of t_4, did not reach the significant level.

Fig. XVII.— Number of leaves per plant



The number of leaves per plant under hand-weeded treatment was more than that under weedy treatment. This holds true under all the counting times. This shows clearly that weeds compete with the potato crop and restrict its meristematic activity, of which the number of leaves is a good indication.

The number of leaves per plant under hand-weeded treatment was greater than the pruned root treatment at all the first three counting times although the difference failed to reach the significant level at the first counting. This means that pruning checked the increase in the number of leaves.

On the fourth count the number of leaves of pruned treatment became greater than those of hand-weeded treatment, but the difference did not reach the significant level. This shows that plants, after suffering a check due to pruning, had resumed their growth and built foliage.

In Fig. XVII the number of leaves per plant under different treatments is plotted against time.

Fig. XVII shows clearly the difference in leaf number due to treatment.

The Dry Weight of Leaves

Table XXIX shows that there is a highly significant difference in weight of leaves per plant due to treatment, time, and treatment x time interaction.

Table XXIXa shows the complete analysis of the dry weight of leaves, and this result is summarised

in the following Table.

Table XXX

Summary of the Analysis of Variance of the Dry Weight of Leaves per Plant

Significance (S) is assumed when the value of F exceeds the 1% point

Variance due to	Significance
Block	-
Treatment	S
Time	S
Treatment x Time	S

The entries in the above Table will be considered in turn.

The variance due to treatment is significant, which means that the three treatments differed in mean dry weight of leaves per plant. Next, it has to be determined where these differences lie. The significant differences in dry weight are distributed as follows:-

There is significant difference between weedy and pruned treatments in favour of pruned treatment and the difference between pruned treatment and hand-weeded treatment is in favour of the latter.

Weeds competed with the potato plants and restricted their foliage growth. Weeds reduced the number of leaves per plant as well as the weight of the leaves or the metabolic functional protoplasm of the plant.

Pruning checked the growth of the plant. The difference in leaf weight between hand-weeded treatment and pruned root treatment in favour of the former is a good indication of this check.

Turning now to the next entry in Table XXX, it

will be noticed that variance due to time is significant. This means that the plants were growing. Treatments are arranged in ascending order as follows:-

Table XXIX a

	Dry Weight of Leaves in gms.
t_1 (16th June)	10.6
t_2 (1st July)	24.8
t_3 (14th July)	34.8
t_4 (28th July)	36.5

$t_3 > t_4$

The difference between t_3 (14th July) and t_4 (28th July) did not reach the significant level. The leaves attained their maximum weight and then remained constant. During this period ($t_3 - t_4$) the plants devoted their activity to size the tubers by translocating most of the metabolites to them. The next entry is the treatment x time interaction.

Treatment x Time Interaction (Table XXIX a)

The total weight of leaves per plant of weedy treatment increased with time. The increment of weight was small, so the difference between t_2 (1st July) and t_3 (14th July); and between t_3 and t_4 (28th July) appeared insignificant.

The total weight of leaves per plant of hand-weeded treatment increased with time although the weight at t_3 (14th July) and t_4 (28th July) remained constant. Weight of leaves reached its maximum at t_3 and remained constant, and the activity of foliage was devoted not to building new foliage but to size the tubers.

The weight of leaves per plant of pruned root

treatment increased with time and the difference between t_3 and t_4 did not reach the significant level.

On 16th June the difference between treatments failed to reach the significant level.

The pruning effect did not show itself on 16th June. The time elapsed between pruning and estimation of leaf weight was too short for plants to show the detrimental effect of pruning on growth of plants.

On 1st July the dry weight of leaves per plant was estimated for the second time, and the analysis shows that there is difference in favour of hand-weeded treatment over both pruned treatment and weedy treatment. On this recording date, pruning started to show its detrimental effect.

On 14th July there was difference between hand-weeded, pruned and weedy treatments, in favour of the hand-weeded treatment. The difference between weedy and pruned treatments was in favour of the former.

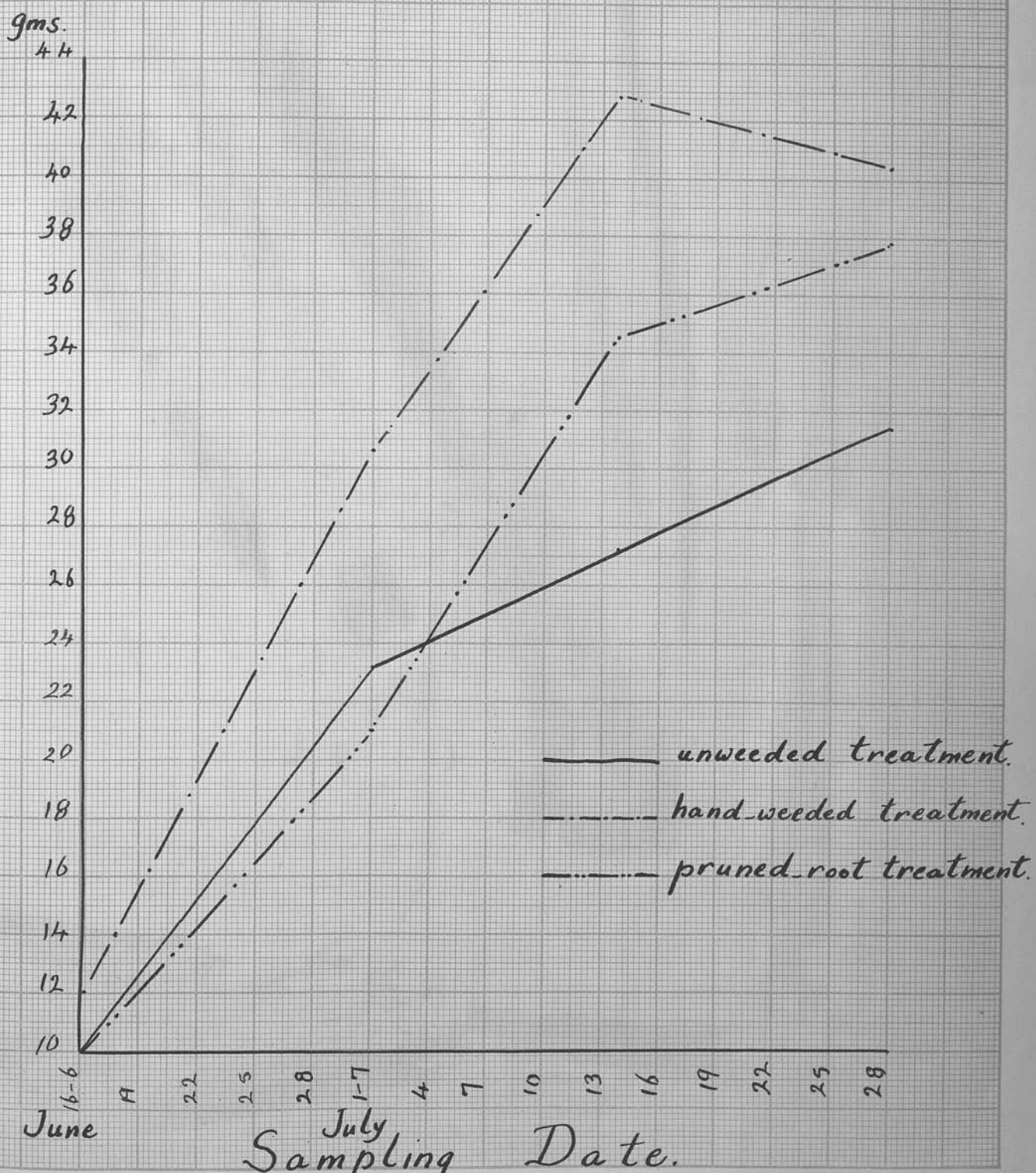
On 28th July the weight of leaves of weedy treatments was less than those of pruned and hand-weeded treatments.

After the check of growth due to pruning, the plants resumed their activity and the difference between the pruned and hand-weeded treatment narrowed and became insignificant on 28th July.

In Fig. XVIII the weight of leaves per plant is plotted against time.

Fig. XVIII.

Dry weight of leaves per plant.



Stems Dry Weight per Plant

Table XXXI shows the analysis of variance of the dry weight of stems. There is difference due to time and treatment.

The weight of stems under different times of sampling could be arranged in ascending order as follows:-

	Weight of stems per plant in gms.
t_1 (16th June)	2.56
t_2 (1st July)	11.92
t_3 (14th July)	23.94
t_4 (28th July)	26.61

This means that the stems dry weight increased with time. The difference in weight of stems between t_4 and t_3 in favour of t_4, did not reach the significant level. The stems dry weight per plant under different treatments, arranged in ascending order, is as follows:-

Table XXXIa

	Weight of stems in gms.		Weight of stems in gms.
Weedy treatment	14.28	Pruned-root treat.	16.18
Pruned-root treat.	16.18	Hand-weeded treat.	18.31

Weeds competed with the potato plants and resulted in a thin stunted stem.

Pruning of roots checked the growth of stems and so the weight of stems under pruned treatment was less than under hand-weeded treatment, although the difference in favour of the latter did not reach the significant level.

Tuber Dry Matter per Plant

Table XXXII shows that there is a significant difference due to time and treatment.

Time (Table XXXII a) This means that the weight of tubers per plant increased with time.

Treatment (Table XXXII b) The total weight of tubers per plant are arranged in ascending order as follows:-

	Dry weight of tubers per plant in gms.
w (weedy treatment)	276.3
p (pruned-root treatment)	317.0
h (hand-weeded treatment)	397.8

Weeds competed with the crop and restricted the growth of the plant, and reduced the relative growth rate, the number of tubers per plant, the photosynthetic system (leaf weight) per plant, and so the output of the plant of weedy plots became much less in comparison with that of the plant of hand-weeded plots.

Pruning of roots checked the growth of the plant, the reduction in the leaf weight being a good expression of this check of growth. The number of tubers per plant was reduced as a result of pruning. The net output, or the yield of pruned treatment, was less than that of the hand-weeded treatment.

Tuber Dry Matter per cent.

The dry matter per cent. of the potato tubers under different treatments was estimated at different stages of the growth period. Tubers were cleaned, cut into small pieces and dried in an oven 105° for 48 hours.

The dry matter percentages were transformed to

degrees ($p=\sin^2 \phi$) which were subjected to the proper analysis of variance.

The analysis of variance (Table XXXIII) shows that there is a difference due to time and treatment.

Time (Table XXXIII a) This means that the dry matter percentages of the tubers increased with time. The difference of the dry matter at t_2 (14th July) over that at t_1 (1st July) in favour of the former did not reach the significant level.

Treatment (Table XXXIII a) The dry matter percentages of tubers of plants of weedy plots was greater than that of plants of hand-weeded or pruned-root treatment.

There was no difference in the dry percentages between that of hand-weeded treatment and pruned-root treatment.

Number of Tubers per Plant

The number of tubers per plant was counted on 1st, 14th and 28th July and 20th August.

The data (Table XXXIV) show that there is a highly significant difference due to treatment. The average number of tubers per plant is 11, 15, 11.2, for weedy, hand-weeded and pruned root treatment respectively. (Table XXXIV a)

The number of tubers per plant of both weedy and pruned root treatment is much less than that of hand-weeded treatment, which is a clear indication that weeds result in the reduction of the number of tubers per plant. The number of tubers of pruned root treatment is much less than that of hand-weeded treatment.

There was no significant difference in number of tubers per plant between pruned root and weedy treatment. There was no difference in number of tubers per plant due to time. This means that the number of tubers per plant was just the same at the different periods of excavation of plants.

Tubers were counted for the first time about 7 days after flowering. The data show that there was no increase or decrease in tuber set after flowering. This observation leads to the belief that the small tubers at the harvest time are the result of the uneven growth rate rather than a late "set". This means that smaller tubers are of the same physiological age as the larger ones, which confirms Clark's (1921) results. (9)

There was no difference due to treatment x time interaction.

Table XXXV shows the number of tubers at different times.

Relation of the Cultural Treatments to Soil Moisture

To study the effect of cultural treatments (hand-weeded, pruned root and weedy treatments) on soil moisture, soil samples were taken on 7th July during a spell of dry weather. Soil samples were taken to the depth of 6 inches. Ten borings were made by soil augeur between plants in each plot of the sub-experiment, the soil from all the borings being thoroughly mixed before drawing the sample. The samples were placed in class bottles which were sealed and taken to the laboratory for soil moisture determination. The soil moisture was calculated on dry weight soil basis. The soil moisture percentages were transformed to degrees ($p = \sin^2 \phi$) and these degrees were subjected to the statistical analysis.

On 7th July, there was a great difference in soil moisture content (Table XXXV) in favour of clean treatments (hand-weeded and pruned root treatments) (Table XXXV a). The loss of moisture in weedy treatment was due to the extra transpiration by the weeds.

There was no difference between hand-weeded and the pruned root treatments. The mean soil moisture % on 7th July was 10%, 13.8%, 13.3%, for unweeded, hand-weeded and pruned root treatments respectively.

The effect of weeds on the mean moisture content of the first 6 inches of the soil showed that the weeds gave a mean decrease of moisture content of 3.5% in comparison with the clean treatments.

The Lateral Extent of the Root System

The lateral extent of the root system was estimated three times during the growing season. It was estimated at 4 inches from the soil surface.

The data (Table XXXVI) show that there is a difference due to treatment, time, and treatment x time interaction.

Time (Table XXXVI a) The lateral extent of the root system increased with time

Treatment (Table XXXVI a) Treatments are arranged in ascending order as follows:-

p (pruned root treatment)
w (weedy treatment)
h (hand-weeded treatment)

Weeds competed with the crop and restricted its lateral root extension.

Lateral extent of the root system of hand-weeded treatment was greater than that of pruned treatment. This is undoubtedly to be expected as pruning cut the roots.

Treatment x Time Interaction (Table XXXVI a)

The lateral extent of the root system of weedy treatment increased with time.

The lateral extent of the root system of hand-weeded treatment at t_2 (1st July) and t_3 (14th July) was bigger than at t_1 (16th June). As between t_3 and t_2 the difference in favour of t_3 did not reach the significant level.

The lateral extent of pruned root treatment at t_3 was greater than at t_1 and t_2. The lateral extent at t_2 was less than that at t_1 although the difference

did not reach the significant level. This is due to the pruning of roots between t_1 and t_2.

The lteral extent of the root system of hand-weeded treatment was greater than that of weedy or pruned root treatments all the time.

There was no significant difference in lateral extent between pruned root and weedy treatment on 14th July. This is because plants were severely pruned on 26th June.

Maximum Depth of Root System

The data (Table XXXVII) show that there is a difference due to treatment, time, and treatment x time interaction.

Time (Table XXXVII a) The depth of the root system increased with time.

Treatment (Table XXXVII a) There is a difference in depth of the root system owing to treatment. Treatments are arranged in descending order as follows:-

	Depth of the root system in cms.
h (hand-weeded treatment)	39.7
w (weedy treatment)	36.9
p (pruned root treatment)	34.3

Weeds competed with the crop and restricted the penetration of roots into the soil.

Pruning of roots restricted the distribution of the root system, a s well as its lateral extent and maximum depth.

Treatment x Time Interaction (Table XXXVII a)

The depth of the root system of different treat-

ments increased with time. The difference between t_1 (16th June) and t_2 (1st July) of pruned root treatment did not reach the significant level.

On 16th June the difference between treatments did not reach the significant level.

On 1st July the difference appeared. The difference between hand-weeded treatment, pruned root treatment and weedy treatment in favour of the hand-weeded treatment, reached the significant level. This held true on 14th July.

On 1st July the difference between pruned root and weedy treatments in favour of the latter was significant. This difference narrowed and the maximum depth of root system of pruned root treatment caught up, and the difference became insignificant on 28th July.

Branching of Primary Roots

This is measured by the number of secondary roots coming out of 1 cm. of a primary root. It was calculated from a sample of 1,000 cms. The sample was taken at random. There was no difference in branching of primary roots due to either treatment or time or treatment x time interaction (Table XXXVIIIa) The number of roots coming out of 1 cm. of primary root was 8.11, 8.12, 7.95 for unweeded, hand-weeded, and pruned root treatment respectively (Table XXXVIIIa). This shows that cultural treatments had no effect on branching of roots.

Root Volume

From the results stated above concerning the

lateral extent and the depth of the root system, it could be said that the root volume (soil occupied by root system) of plants of hand-weeded treatment is bigger than that of pruned root or weedy treatments.

Derived Data

This section is devoted to the study of the growth and development of the plant. Certain data are required for this study: periodic dry weight, measure of the whole plant and its various parts roots, tubers, leaves, etc., through its life.

There are different methods of representing the results. Herein is a report of

(i) Relative growth rate R.G.R.

(ii) Relative leaf growth rate R.L.G.R.

(iii) Net assimilation rate N.A.R.

(iv) The relative proportion of plant parts throughout the life cycle.

Relative Growth Rate

This represents the rate at which the fresh material is continuously added to the plant over a definite period (Blackman 1919)[6] It could be used as an expression of the efficiency of the plant in production of dry matter.

The relative growth rate of a plant of every treatment was calculated by the formula -

$$\frac{\text{Log}_e\ w_2 - \text{Log}_e\ w_1}{t_2 - t_1}$$

where w_2 is the dry weight of the plant at (t_2) the end of the week and w_1 the dry weight of the plant at (t_1) the beginning of the week.

The relative growth rate was then subjected to the statistical analysis.

The Relative Growth Rate Curve

The relative growth rate of the plant under different cultural treatments are plotted against time (Fig. XIX)

While discussing the relative growth rate curve (R.G.R), it should be kept in mind that from 80 - 90% of the dry weight of the plant is the result of the process known as carbon assimilation, and the actual percentage of the dry weight of the plant derived from the mineral of the soil is relatively small.

From the above it could be stated that the relative growth rate at any time is almost equal to the difference between the rates of assimilation and respiration per 100 gm. dry weight at that time.

The general trend of the curve (Fig. XIX) shows that the R.G.R. fell with time. This fall shown in the curve must be due to a decreasing difference between the rate of assimilation and the rate of respiration per unit dry weight during this time of plant growth.

The R.G.R. of the potato plant under the three different cultural treatments were calculated between

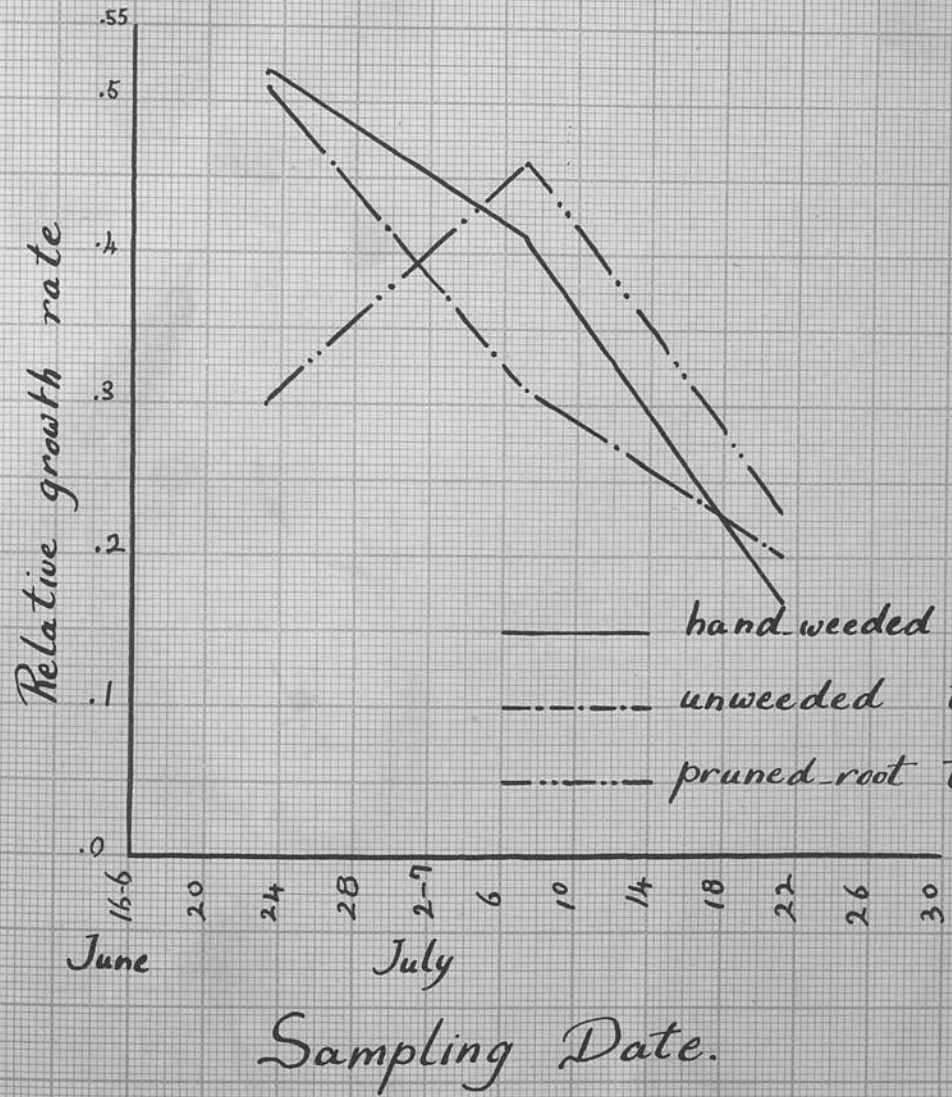
16th June - 1st July (first interval)
1st July - 14th July (second ")
14th July - 28th July (third ")

The data show that there is significant difference due to treatment x time interaction and time (Table XXXIX)

Fig. XIX.

Curves of relative growth rate.

(gm. per gm. per week.)



Sampling Date.

Treatment x Time Interaction (Table XXXIXa)

The R.G.R. of weedy treatment decreased with time. This holds good under hand-weeded treatment although the difference between the second interval and the first interval in favour of the former did not reach the significant level.

The R.G.R. of pruned root treatment at the second interval was more than at the first interval. The pruning of roots checked the growth and the small R.G.R. is a good expression of this check.

The plant after pruning built its roots and resumed its activity, and the R.G.R. increased. Then the R.G.R. decreased with time.

On first interval (16th June - 1st July) the R.G.R. of plants of weedy and hand-weeded treatments were bigger than plants of pruned root treatment. This is due to the check of growth as a result of pruning roots. The difference in R.G.R. between weedy treatment and hand-weeded treatment in favour of the latter did not reach the significant level.

On second interval (1st July - 14th July) the pruned root plants rebuilt their root systems and resumed their activity, and the R.G.R. exceeded that of weedy and hand-weeded treatment. The difference between pruned root and hand-weeded treatments in favour of the former did not reach the significant level.

On third interval (14th July - 28th July) there was no significant difference in R.G.R. due to treatment.

Time The relative growth rate decreased with time. (Table XXXIX a) The decrease in R.G.R. with time is due to a decreasing difference between the rate of assimilation and the rate of respiration per unit dry weight

The Relative Leaf Growth Rate

It is analogous to the relative growth rate.

It was calculated by the equation:

$$\frac{\log_e L_2 - \log_e L_1}{t_2 - t_1}$$

where L_2 is the dry weight of leaves per plant at the end of the week (t_2)

L_1 is the dry weight of leaves per plant at the beginning of the week (t_1)

The analysis of variance of the relative leaf growth rate (R.L.G.R.) (Table XL) shows that there is a difference due to time and time x treatment interaction.

Time (Table XLa) The R.L.G.R declined with time.

Treatment x Time Interaction (Table XLa)

The pruned root treatment had the smallest R.L.G.R. at the first interval (14th June - 1st July), owing to the restriction of growth due to the pruning of roots.

The difference in R.L.G.R. between weedy, pruned root and hand-weeded treatments did not reach the significant level.

On the second interval (1st July - 14th July) the pruned root treatment restored its activity and its R.L.G.R. became higher than weedy treatment. The difference in R.L.G.R. between pruned root

treatment and hand-weeded treatment in favour of the former did not reach the significant level.

The R.L.G.R. decreased with time. This holds true under the three treatments under study, but one difference in the case of pruned root treatment in R.L.G.R. between first interval and second interval just failed to reach the significant level.

Net Assimilation Rate

Net assimilation rate (N.A.R.) or unit leaf rate was developed as a tool in the quantitative analysis of plant growth. It is defined as the rate of increase in the dry weight of a plant per unit of active "growing material". The growing material refers to any attribute of the plant which is primarily concerned in carbon assimilation. Thus it could be taken as a measure of the "internal fact or" for growth.

Rate of carbon assimilation is usually expressed in leaf area basis. Thus it can be assumed that leaf area is an adequate measure of active growing material.

Net assimilation rate was first calculated in 1917 by Gregory (15) but it was left to Briggs, Kidd and West 1920 to formulate the methods of growth analysis (7). In view of the difficulty or even impracticability of measuring leaf area of plants especially under field conditions, the leaf area was replaced by leaf weight . (Growther 1934 (16); Ballard and Petrie 1936 (3); Williams 1936 (52); Heath 1937 (19).

In this study the N.A.R. was calculated by the following equation:

$$E = \frac{w_2 - w_1}{t_2 - t_1} \times \frac{\text{Log}_e L_2 - \text{Log}_e L_1}{L_2 - L_1}$$

Where:

E = Net assimilation rate

w_2 = Weight of the plant at the end of the week t_2

w_1 = " " at the beginning of the week t_1

L_2 = Leaf weight of a plant at the end of the week t_2

L_1 = " " " at the beginning of the week t_1

The N.A.R. of plants of every plot of the sub-experiment was calculated for the intervals of:-

1st interval (16th June - 1st July)
2nd " (1st July - 14th July)

The difference in N.A.R. due to time failed to reach a significant level; this shows that the N.A.R. was more or less constant during this part of the life cycle of the plant (Table XLI). The main effect of treatments on N.A.R. failed to reach the significant level.

Treatment x Time Interaction

There was no significant difference due to treatment x time interaction. The N.A.R. (gm. per gm. per 7 days) for the different treatments is shown in Table XLIa)

The Effect of Age on N.A.R., R.G.R., and R.L.G.R.

Physiological processes change with age, and these changes are of considerable interest. Information about these changes may be obtained by the study of derived data. (N.A.R., R.G.R., R.L.G.R.)

The results show, as stated above, that the N.A.R. per unit leaf weight estimated between 16th June - 1st July and 1st July - 14th July had no general significant downward trend in these periods. This holds true for the three treatments under study.

On the other hand, R.L.G.R. fell significantly with time (Table XLa). Because N.A.R. had no downward trend, the fall in R.L.G.R. implies that an increasing proportion of the products of photosynthesis as time proceeded was used for tubers, stems, etc. As a consequence, the ratio of leaf weight to total dry weight of the plant fell with time (Table XLI).

The R.G.R. showed a downward trend with time although the difference did not reach the significant level between the 1st interval and the 2nd interval. This is the result of a decreasing proportion of the plant weight consisting of assimilating material. The rate of fall of R.G.R. was less than that of R.L.G.R. because the increasing proportion of assimilates going to the stem, tubers, etc., was included in the total dry weight and not in the leaf dry weight.

The Relative Proportions of Plant Parts throughout the Life Cycle

The relative proportions of plant parts throughout the life cycle of the potato plant were estimated:-

(i) $\frac{\text{Stolons-root dry weight}}{\text{Total dry weight of a plant}} \times 100$

(ii) $\frac{\text{Tuber dry weight}}{\text{Total dry weight}} \times 100$

(iii) Foliage dry weight

The data show that during adolescence, roots and foliage form most of the plant; later the tubers become a fraction of increasing relative importance.

The successive phases of ontogeny are thus shown, in which growth of roots, foliage and tubers respectively preponderate. Thus the first stage of growth is shown by the growth of roots, emergence of main shoots and expansion of leaves.

The second stage opens with the rapid growth of axillary shoots below or above ground. A high proportion of metabolites was translocated to tubers. The proportion of metabolites going to foliage declined as shown by the decreasing proportion of foliage to total weight of a plant and an increasing proportion of metabolites going to tubers, as indicated by the increasing ratio of tubers to total weight.

THE MAIN EXPERIMENT

This experiment is devoted to the study of the combination of the methods of cultivation with the hand and no hand-weeding between plants.

I Methods of Cultivation

c_0 No cultivation

c_1 Inter-row cultivation with tines 6" from the plants (wide inter-row cultivation). Treatments carried out two times.

c_2 Same as c_1 but treatments carried out three times.

c_3 Inter-row cultivation with tines 8" from the plant (narrow inter-row cultivation). Treatments carried out two times.

c_4 Same as c_3. Treatments carried out three times.

c_5 Inter-row cultivation with tines 6" from the plant in the first inter-row cultivation. In the 2nd inter-row cultivation tines were 8" from the plant.

c_6 Same as c_5 but inter-row cultivation carried out for the third time with tines 8" from the plant.

N.B. There are two intensities of inter-row cultivation two times and three times. When tines are 8" from the plant, inter-row cultivation is considered as narrow. When tines are 6" from the plant inter-row cultivation is considered as wide.

There are three widths of inter-row cultivation under this study:-

(i) Wide inter-row cultivation

(ii) Narrow " "

(iii) Wide inter-row cultivation in the first cultivation followed by narrow inter-row cultivation in the second or in the second and the third inter-row cultivation.

II After inter-row cultivation, weeds between

plants were eliminated by hand-pulling or left to grow and compete with the crop.

The Lay Out (Plate VIII)

This experiment is of split plot in randomised block system. This procedure was adopted under this study because inter-row cultivation necessitates long plots.

There were seven plots for the seven methods of cultivation. Every main plot was split crosswise into two sub-plots for hand and no hand-weeding between plants. The seven whole plots were arranged in randomised blocks and the treatments of the sub-plots were arranged at random within each whole plot.

There were four blocks comprising 28 main plots. Every plot was of four drills wide and 74 feet long. Drills were 27 inches apart and the plant interval was 14 inches.

Replicates were 15 feet apart from each other to provide space for turning round of the tractor.

Every plot was split into two sub-plots, each 37 feet long.

Planting

The experiment was conducted at Dryden Mains Farm, Steading Field East. The soil is light and soil pH was 6.2 at time of planting.

The area was cropped with swedes harrowed and ploughed in winter, harrowed in spring, ridged on 21st April, 1952, and fertilizer of 8 cwt. per acre (potato crop main fertilizer) was applied.

Plate VIII.

MAIN EXPERIMENT

B_1 74'	h_1 . c_1.	h_0 .c_5 .	h_1 c_3	h_1 c_2	h_0 . c_0.	h_0 .c_6 .	h_1 c_4
	h_0	h_1	h_0	h_0	h_1	h_1	h_0

15 feet

B_2	h_0 c_4 .	h_0 c_6 .	h_1 c_3	h_0 . c_5.	h_1 c_2 .	h_0 c_1	h_1 . c_0
	h_1	h_1	h_0	h_1	h_0	h_1	h_0

B_3	h_1 c_2 .	h_1 c_1	h_0 . c_0	h_1 . c_6.	h_0 c_4 .	h_1 c_3	h_0 . c_5
	h_0	h_0	h_1	h_0	h_1	h_0	h_1

B_4	h_1 c_2 .	h_1 c_3	h_0 . c_5	h_0 . c_6.	h_1 c_4 .	h_0 c_0	h_1 . c_1
	h_0	h_0	h_1	h_1	h_0	h_1	h_0

B Replicate

c_0 No cultivation

c_1 Inter-row cultivation with tines 6" from the plants Treatments carried out two times.

c_2 Same as c_1 but treatments carried out three times.

c_3 Inter-row cultivation with tines 8" from the plant. Treatments carried out two times.

c_4 Same as c_1 but treatments carried out three times.

c_5 Inter-row cultivation with tines 6" from the plant in the first inter-row cultivation. In the second inter-row cultivation tines were 8" from the plant.

c_6 Same as c_5 but inter-row cultivation carried out for the third time with tines 8" from the plant.

Planting and splitting ridges was on 22nd April, 1952. The land was chain-harrowed on 6th May.

Experimental Operations were as follows:-

1.	First inter-row cultivation	5th June, 1952.
2.	Hand-weeding between plants	7th June, "
3.	Second inter-row cultivation	20th June "
4.	Third inter-row cultivation	1st July "
5.	Ridging	4th July "

General Observation on the Weed Population

Poa annua, Dactylis glomerata, Agropyron caninum were the most dominant weeds in the field. Stellaria media, Brassica sinapsis, Plantago major, Tanacetum vulgare and cnicus arvensis were also found in the field.

The weed density in the experiment was much less than the weed density in the last year's experiment. This is largely because swede is a smothering crop and the dry spell during the early growth period of potatoes had an effect in checking the number of weeds expected to germinate in the early growth period.

Hand-pulling of weeds between plants on ridges was done once only in this season and these hand-weeded treatments were kept practically clean during the growth period without any more hand-pulling.

Nitrogen deficiency in the uncultivated unhand-weeded treatments was observed by the visual methods of diagnosis. Symptoms of nitrogen deficiency was very obvious. Plants were stunted, leaves were small and pale green in colour, and the shoots were thin and upright. The older leaves turned yellow

and shed early. Maturity of plants was a little earlier.

The Yield

Plants of this experiment were not touched and no observations on growth of plants, that is, leaf number, plant height, etc., were recorded to get the yield without interference whatsoever with plants.

Fifty-six plants of every sub-plot were lifted after allowing for guard rows and edge plants.

All potatoes were lifted by hand on 29th and 30th September and passed over a 2" riddle. Potatoes were sorted into three grades:

Ware passed over a 2" riddle

Seed between 2" - 1¼"

Chat less than 1¼"

The analysis of variance of the gross yield is shown in Table XLIII. Ware percentages of every sub-plot were estimated. These percentages were transformed to degrees $p = \sin^2 \phi$ (Fisher and Yates 1949 (14). These degrees were subjected to the statistical analysis. Table XLIII shows the analysis of variance, total yield and ware percentages.

Table XLIV summarises the yields of potatoes under the various treatments. It gives in addition the per cent. ware in the crop.

Effect of Hand-Weeding between Plants on Yield

Table XLIII shows that there is a significant difference at 1% level due to hand-weeding and no hand-weeding between plants. The total yield in tons per acre for hand-weeding and no hand-weeding

were 16.85, 14.94 respectively (S.E. ± .247).

Elimination of weeds between plants after inter-row cultivation is very important. Weeds compete with the crop for nutrients, moisture and light.

Hand-weeding between plants is replaced by hand-hoeing in practical farming. Hand-hoeing is very important because there is no other mechanical means for the destruction of weeds between plants.

The Effect of Weeds on the Yield

The zero cultivated treatments where weeds were eliminated by hand-pulling gave a heavier yield than the zero cultivated treatments where weeds were allowed to grow and to compete with the potato crop. The uncultivated unhand-weeded treatment gave .74% of yield as compared with uncultivated hand-weeded treatment. This confirms farmers' beliefs as well as the results of experiments carried out by other investigators.

It cannot be determined under this experiment whether this depression is due to one or more of the following factors:-

(i) mineral nutrients

(ii) moisture

(iii) light

(iv) toxicity of soil by weeds

As stated elsewhere (sub-experiment) weeds competed with the crop and restricted the leaf number, the leaf weight, the stem weight, and the number of tubers per plant.

The physiological activity of plants in weedy

plots was restricted and their output became inferior than plants in hand-weeded plots.

The Effect of the Soil Mulch on the Yield

Inter-row cultivations do two things: they kill the weeds growing between the rows and they loosen the surface of the soil.

Elimination of weeds in zero cultivation by hand-pulling resulted in no considerable soil mulch.

The difference between inter-row cultivated hand-weeded treatments and the zero cultivated hand-weeded treatments should be due to the dust mulch and the destroyed surface feeding root system in the stirred area.

The mean yields in tons per acre for uncultivated hand-weeded treatment and inter-row cultivated hand-weeded treatment were 17.56, 16.74 respectively (S.E. $\pm$ .673).

The difference between these two treatments failed to reach the significant level. This shows that there was no benefit due to dust mulch. The harm effect of inter-row cultivation due to destruction of the surface feeding roots in the stirred area out-weighed the benefit expected from the dust mulch, although the difference in favour of zero cultivated hand-weeded treatment failed to reach the 5% level of significance.

This confirms the results of other experiments in Great Britain and U.S.A., but contradicts the deep rooted farmers' belief.

The Effect of Width of Inter-row Cultivation on Yield

There was no significant difference in the gross yield of potatoes due to the width of inter-row cultivation under this study. The total yield in tons per acre for wide inter-row cultivation, narrow inter-row cultivation and wide inter-row cultivation in the first cultivation followed by narrow inter-row cultivation were 15.72, 15.63, and 16.41 respectively (S.E. ± .336).

This shows that the red skin variety was not sensitive to the width of inter-row cultivation in this study.

The destruction of roots did little to disturb the well balanced system between the roots and the foliage.

The Effect of the Intensity of Cultivation on the Yield

The yield in tons per acre was 16.02 and 15.96 for two times and three times of inter-row cultivation respectively (S.E. ± .275).

The insignificant difference between these two treatments shows that the third additional inter-row cultivation did not benefit the crop.

Tuber Size

Table XLIII shows that there is a significant difference at 1% level due to hand and no hand-weeding between plants. There is no significant difference due to methods of cultivation or method of cultivation hand-weeding interaction. This result is similar to the total yield result.

The ware per cent. was 84.4, 81.6 for hand-weed-

ing between plants and no hand-weeding between plants. Hand weeding between plants resulted in an increase in total yield and in ware per cent.

The result of the experiment was that the percentage of ware was not affected by the cultivation treatments (width of inter-row cultivation and intensity of inter-row cultivation). Weeds affected tuber size.

D I S C U S S I O N

1. The Emergence of Plants

The emergence of plants is known to be influenced by and depend upon many factors, one of which is the depth of planting.

Hardenburg 1949 (18) stated that shallow planting hastens the emergence of plants, while Moore 1937 (30) does not seem to agree and believes that shallow planting takes more time to emerge.

The result of this present work favours Hardenburg's statement as it was found that shallow planting hastened the emergence of the plants (Table II, XXII), the difference being two days in the first season 1951 and one day in the second year 1952.

The reason for these conflicting results (Moore's and Hardenburg's) seem to be due to particular environmental conditions prevailing at the time of planting and germination. The tuber needs a certain optimum soil moisture to germinate, which in the case of Moore's experiment happened to be found deep in the soil where he put his tubers. There was less moisture in the case of medium or shallow depth of planting (Moore 1937).

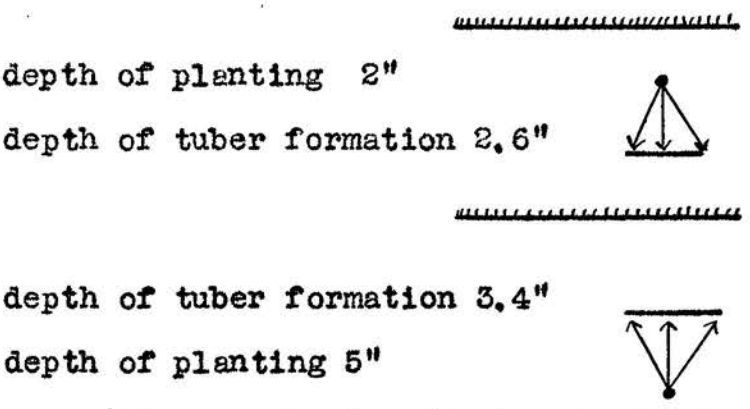
2. The Depth of Tuber Formation

Tubers seem to be formed within a narrow range at a particular level in the soil.

In 1916 Zavitz (56) found that when seeds were planted near the surface of the soil (shallow planting) the tubers are formed a bit deeper than the seeds, while if the seeds were deeply planted the

tubers are formed near to the surface.

This was further confirmed in our experiment, as when the seeds were planted at 2 inches the tubers were formed at 2.6 inches, while when the seeds were planted at a depth of 5 inches the tubers were formed at 3.4 inches.



(Diagram showing the level of tuber formation in the case of shallow and deep planting).

Thus it seems that at a depth of 2.6" to 3.4" the soil condition (moisture, aeration and temperature) is most favorable for tuber formation.

It is suggested that tubers should be planted at a depth of approximately 6 inches, because the depth of the tubers is decreased by the chain harrow treatment. Chain harrowing removes the soil from the top of the ridge, thereby raising the level of the tubers to the area where there is the greatest development of tubers.

3. The Root System

a) General character

Ten Eycke ~~1899~~, 1900 (45), Weaver 1926 (49) and Farris 1934 (13a) have shown that the primary roots take a horizontal course.

In the present study these primary roots took

a rather diagonal course. But this is not a point of major difference as in the previous experiment they used the level cultivation method whereas the ridge culture method was used in the latter. This was also shown by Moore 1937 (30) as he found the roots to take a horizontal course in the level cultivation and a diagonal course in the ridge culture. Therefore, the result of the present experiment is in agreement with the result of Moore's under ridged culture.

b) Lateral extent

The lateral spread of the root system varies very much according to the variation in the environmental conditions, both edaphic and climatic, and to the variety of the plant itself. It has been estimated to vary from about 24 - 40 inches (Ten Eycke (45), Rotmistrov (37), Weaver (49), Moore (30), Artschwager (1).

The lateral spread for hand-weeded treatment in this experiment was 54 cms. after 73 days after planting for Kerr's Pink (1951) andit was 43 after 91 days after planting for Red skin variety 1952. The lateral spread in my experiment varied according to the treatment. The best result was obtained when there was no weed competition at all. (The plot was hand-weeded and roots were not pruned.) (Table VIIIa, XXXVIa) Where the roots were pruned their extent was less than the hand-weeded treatment but this does not differ from the plots in which plants suffered weed competition.

The restriction of the root extent in the unweeded treatment is obviously due to less carbohydrates being manufactured by the plants and to less carbohydrates transferred to the root system, as the weeds compete with the potato plants for the soil nutrients, soil moisture and light, causing them to shoot up a smaller and poorer foliage (Tables XIa, XIb, XXIXa, XXXIa).

This was also found to be the case in some other crops. Pavlychenko and Harrington 1937 (33), Weaver and Kramer 1932 (50), Yocum 1937 (55), Coile 1940 (10).

The pruning of the roots showed that the inter-row cultivation - which in itself is a pruning process particularly when the vegetative system is about 8 - 10 inches (as then the lateral spread of the roots is so great that inter-row cultivation cuts off a considerable proportion of the roots) - restricts the extent of root system. Consequently it is advised that inter-row cultivation, which is important to rid the plants from the competition of weeds and to afford the dust mulch necessary for ridge building, should be applied early in the growth season, so that it does not hurt much of the root system.

c) <u>The maximum depth of the root system</u>

The different treatments to which plants were subjected, namely hand-weeding, pruning of the roots and allowance of weed competition, seem to affect the depth of the root system in a very similar way as they do the lateral extent of the root (Table IXa, XXXVIIa)

Here too, there is a very great variation in the depth of the roots found by different workers. It has been estimated to vary from 18 - 97 inches. Ten Eycke (45), Schulze (43), Rotmistrov (37), Weaver (49), Moore (30), Artschwager (1). This variation in maximum depth of the root system is also due to the difference in the environmental con ditions, both edaphic and climatic, and the variety grown.

It is worthwhile to mention here that our results show that the farmers' belief that pruning of the root system is conducive to a deeper penetration by the remaining roots, has no scientific basis.

Obviously, the efficiency of the root system in the hand-weeded plot is much higher than that in other treatments (unweeded treatment, pruned-root treatment) and is due to the greater horizontal and vertical extent of its root system, which makes the volume of the soil available to the plant much greater.

4. The Yield

Inter-row cultivation has the advantage of killing the weeds and of helping in the formation of dust mulch. Its only disadvantage is its harmful effect on the root system.

a) There is no doubt that the killing of weeds should give us a better yield as the weeds do share the food, particularly the nitrogen and the moisture, with the crops. Their competition does not seem to be for moisture as much as for the other nutrients, at least under Scottish environmental conditions.

So it appears that the major injury to the crops results from the weed competition for nitrogen. The smaller number of leaves of unweeded plants is a good indication of the nitrogen deficiency (Table XXVIIIa).

b) The formation of dust mulch does not seem to be a credit to the inter-row cultivation, despite the erroneous belief of the farmers that it holds the moisture in the soil. Lombard 1936 (24), Moore 1937 (30), Russell and Keen 1938 (41), Periera 1941 ($\frac{35}{36}$), Russell 1949 (39, 40).

In this study soil mulch did not benefit the crop; on the contrary, the harmful effect of inter-row cultivation of destroying the surface feeding roots outweighed its beneficial effect. This holds true in the case of Kerr's Pink (Table XVIIIf). Under narrow inter-row cultivation, where not much harm was done to the roots of Kerr's Pink, there was no difference between this treatment and zero cultivated hand-weeded treatment (Table XVIIIg).

There was no significant difference between inter-row cultivation, hand-weeded treatment and zero cultivated hand-weeded treatment in the case of Red skin 1952, because little harm was done to roots, their lateral spread being much less than that of Kerr's pink.

Nevertheless, if only for its weed killing effect, inter-row cultivation is beneficially practised by farmers. Further, it helps the soil to give a better yield of the succeeding crop in the rotation.

It has also the advantage of economising harvesting work and time spent on spraying. So long as ridging is the basis of potato culture, inter-row cultivation will be found to be the easiest way of obtaining the tilth needed for ridging.

c) Intensity of cultivation and its effect on yield when weeds between plants are pulled after inter-row cultivation

It appears that there is no point in going beyond a certain number of inter-row cultivations, because the yield usually decreases rather than increases by increasing the frequency of inter- row cultivation. This was observed by Keen 1938 (21), Russell and Keen (41), and Russell 1949 (40), who found that intensive cultivation of the root crops results in depressing the yield.

In the present study it was also found that the yield does not increase if the number of inter-row cultivations is increased from twoto three, the reason being that late inter- row cultivation destroys a considerable proportion of the roots as well as some leaves.

But this need not lead to the cessation of intensive inter- row cultivation. In this connection the following questions merit careful consideration before these extra inter-row cultivations can be profitably omitted.

(i) Will the subsequent crops in the rotation benefit by these operations? The answer depends on weed population. Again, it should be emphasized that inter-row cultivation is done with the object

of weed destruction. Any work in excess of weed destruction is unproductive. If the potato is a clean crop in the rotation, then certain perennial weeds may be best killed by frequent grubbings, and this would pay and benefit the succeeding crop in the rotation.

(ii) How far is the labour of extra cultivation offset by a saving of time in harvesting potatoes? On light soils very slight ridging will be adequate if a lifting-plough or other suitable implement is used for harvesting. The belief that the crop will gain by high ridging should be combatted. The only effect on the crop will probably be extra root-pruning and the grower will find himself committed to deeper initial grubbing at additional cost.

d) The width of inter-row cultivation (weeds were pulled after inter-row cultivation)

Apparently the effect of the width of inter-row cultivation depends on the lateral extent of the roots and that in turn varies with the variety of the plant, so that where a particular variety may respond to more than one width of inter- row cultivation, another variety might show a better effect with one definite width of cultivation. It was stated that whereas the Red Skin variety gives similar yield when inter-row cultivated at a width of 6 or 8 inches or even at a width of 6 and then 8 inches from the plant, the Kerr's pink was more affected than when cultivated at a width of 6 than when cultivated at 8 inches. Kerr's pink gave less

yield in the first case where the tines were nearer to the plants. This may be explained by the fact that the extent of the roots of Kerr's pink was greater than those of the Red skin.

From this study the author recommends the close inter-row cultivation, say 6 inches from the plant in the earlier stages of development and wide inter-row cultivation, say 8 inches from the plant, when the plants advance in growth. This would facilitate hand-hoeing at the earlier stages of growth (as the part left to be hoed will be narrow) without any serious interference with the roots, and compel us to use narrower cultivation later on to ensure their intactness.

e) Hand-weeding between plants

After the inter-row cultivation, what remained of weeds between the plants were pulled by hand. This was found to give a better yield (Table XVIIIb). The farmers(belief agrees with this, and the works of other investigators prove the importance of elimination of weeds.

f) Effect of depth of planting on yield

Lorenz 1945 (26) examining the effect of depth of planting in the yield found that a depth of 4 or 6 inches is better than 8 inches, while Hardenburg 1949 (18) and Moore 1937 (30) did not find any difference in the yield whether planted shallow or deep. Although in my work the shallow planting gave a higher yield than the deep planting, the difference is statistically insignificant (Tables XVIII, XXVI)

It should be mentioned that all the present work was carried out on a light soil. It will probably be found that the treatments advocated will be practicable on most sandy soils. They are less likely to succeed on heavy soils for the following reasons:-

(i) Heavy soils tend to bake into clods on the surface unless protected by mulch.

(ii) Heavy soils tend to cling to the tubers and this is not easy to remove.

(iii) Stiff clay soils are not well suited to potato growing.

S U M M A R Y

1. This work was designed to study the effect of inter-row cultivation on the growth and yield of the potato crop.

2. A comparison between the effect of some other cultural treatments was studied. These treatments are:-

depth of planting
width of inter-row cultivation
intensity of inter-row cultivation
hand and no hand-weeding between plants.

3. Shallow planting was found to hasten the emergence of the plants by a day or two.

4. The roots tended to extend diagonally rather than horizontally.

5. Weed competition and pruning of root systems restricted the lateral spread and the maximum depth of the root system.

6. Hand-weeded plants were more vigorous than weedy plants or root-pruned plants.

7. Weed competition resulted in fewer tubers, fewer leaves and lighter stem, and a show down in the relative growth rate.

8. Pruning decreased the relative growth rate at first. Later, plants resumed their activities so that the relative growth rate rose beyond that of hand-weeded, unpruned plants. It remained at a higher level until it reached the same value for hand-weeded unpruned-root plants.

9. Weed competition resulted in an insignificant decrease in the net assimilation rate. Pruning of

the root system did not affect the net assimilation rate.

10. The methods of cultural treatments did not affect the branching of roots.

11. Weeds reduced the soil moisture percentages and increased the tuber dry matter per cent.

12. The tuber was found to be formed at a level deeper than the seed (tuber) if the latter was near the surface of the soil and at a level higher than the seed in the case of deep planting.

13. The weed competition affected the crop and consequently caused a decrease in the yield.

14. Soil mulch appeared to have no effect on yield.

15. It may be concluded therefore that inter-row cultivation benefits the crop through restricting the growth of weeds only and not by creating soil mulch.

16. It is not of any use for potato yield to carry on with cultivation more than twice (when weeds between plants were hand-pulled).

17. Shallow planting gave a slight but statistically insignificant increase in the yield.

18. Hand-weeding between plants resulted in a better yield.

19. Narrow inter-row cultivation (tines 8 inches apart from plants) benefited the yield over wide inter-row cultivation (tines 6 inches from plants) when weeds were pulled by hand after inter-row cultivation. This holds true in Kerrs' pink. This

does not apply in the case of Red skin variety, which is due to the fact that the lateral spread of the root system is greater in the case of Kerrs' pink.

20. It is worthy of note that treatments which encouraged a high yield also gave a higher percentage of ware.

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Table I.

GERMINATION RATE INDEX

Analysis of Variance

Due to	d.f	S.S	M.S.S.
Total	39	260563.9	
Block	3	8579.3	2859.7
Depth of planting	1	147622.5	147622.5 **
Error	35	104362.1	2981.77

Table II.

Per Cent. of Plants Come-Up at Stated Dates

Planting Depth	Date of Counting							
	12th June	14th	16th	18th	20th	22nd	24th	28th June
d_1 (2")	31.2	50.5	70.5	82.1	90.2	94.3	96.3	100
d_2 (5")	13.2	31.4	51.6	63.7	77.2	85	92.2	100

Table III.

Per Cent. of Come-Up of Plants at Different Periods

Planting Depth	Date of Counting						
	12-14th June	14 - 16	16 - 18	18 - 20	20 - 22	22 - 24	24 - 28
d_1 (2")	19.3	20	11.6	8.1	4.1	2.	3.7
d_2 (5")	18.2	20.2	12.1	13.5	7.8	7.2	7.8

Table IV.

Per Cent. of Number of Tubers at Different Levels from Soil Surface.

Planting Depth	Depth from soil surface in inches							
	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8
d_1 (2")	19.9	14.8	26.5	20.9	14.0	3.3	.6	–
d_2 (5")	9.8	10.2	21.4	23.7	22.6	9.6	2.3	.4

Table V.

Per Cent. of Number of Tubers at Stated Level

Planting Depth	Depth from soil surface in inches							
	1	2	3	4	5	6	7	8
d_1 (2")	19.9	34.7	61.2	82.1	96.1	99.4	100	–
d_2 (5")	9.8	20.0	41.4	65.1	87.7	97.3	99.6	100

Table IV a

FINAL STAND OF THE PLANT

Analysis of Variance

Due to	d.f	S.S	M.S.S.
Total	79	279.55	
Plot	39	141.55	
M - Method of Cultivation	4	8.30	2.07
D - Depth of planting	1	.20	.20
B - Replicate	3	11.04	3.68
Error (a)	31	122.01	3.93
Sub-plot	40	138	
H - Hand-weeding	1	.45	.45
Error (b)	39	137.55	3.52

M.D, M.H, D.H, M.D.H were not calculated for their negligible importance.

Table IV b

Number of Plants per Sub-Plot

	C_o		C_1		C_2		C_3		C_4	
	d_1	d_2	d_1	d_2	d_1	d_2	d_1	d_1	d_1	d_2
ho (no hand-weeding)	106	109	107	107	105	106	107	108	109	109
h_1 (hand-weeding)	107	106	106	107	109	107	108	106	107	106

d_1 2" depth of planting

d_2 5" " " "

Table VI

WEED DENSITY (DRY MATTER METHOD)

Analysis of Variance

Due to	d.f	S.S.	M.S.S.
Total	37	60455.25	
M - Method of Cultivation	3	47240.25	15746.75 **
D - Depth of Planting	1	.70	.70
M.D	3	96.30	32.1
Block	1	.08	.08
T - Time of Counting	2	2662.12	1331.06 **
M.T	6	9486.88	1581.14 **
D.T	2	7.43	3.71
M.D.T	6	95.07	15.84
Error	23	866.42	37.67

M.D Method of cultivation, depth of planting interaction.
M.T " " " time of sampling "
D.T Depth of planting " " " "
M.D.T " " " " " " method of cultivation interaction.

Table VI a

Weight of Dry Matter of Weeds in gms. per sq. m.

Time of Sampling	Method of Cultivation				Mean	
	c_0	h	c_1	c_2		
t_1 (2nd July)	60.75	5.75	19.75	11.5	24.43	
t_2 (19th July)	67.75	2.75	35	23.75	32.31	± 1.534
t_3 (14th August)	129.	4.5	22.75	14.25	42.12	
Mean	85.8	4.33	25.83	16.5		

c_0 No weeding ± .5599 c_1 narrow inter-row cultivation
H Hand-weeding c_2 wide " " "

M.T ± 3.068

Table VII

NUMBER OF WEEDS (QUADRAT METHOD)

Analysis of Variance

Due to	d.f	S.S	M.S.S.
Total	159	18304.65	
Plot	39	8271.4	
M - Method of Cultivation	4	2829.83	707.45 **
D - Depth of Planting	1	11.95	11.95
T - Time of Counting	1	960.27	960.27 **
M.D	4	621.87	155.46
M.T	4	255.05	63.76
D.T	1	24.13	24.13
Error (a)	24	3568.25	148.67
Sub-plot	120	10033.25	
H - Handweeding	1	3397.75	3397.75 **
M.H	4	658.37	164.59
D.H	1	369.38	369.2
T.H	1	439.38	439.38
Error (b)	113	5168.37	452.81

Second and third order interactions were sacrificed for their negligible importance.

Table VII a

Number of Weeds per Square Metre

Sampling Time	Method of Cultivation					Mean	
	c_0	c_1	c_2	c_3	c_4		
t_1 (2nd July)	29.1	30.0	28.6	20.6	20.7	25.8	± 1.36
t_2 (8th July)	38.1	32.6	31	26.3	25.6	30.7	
Mean	33.6	31.3	29.8	23.4	23.1		

± 2.154

Table VIII

LATERAL EXTENT OF ROOT SYSTEM

Analysis of Variance

Due to	D.f	S.S	M.S.S.
M.	3	380.5	126.83 **
D.	1	6.72	6.72
T.	2	3165.58	1582.79 **
M.T	6	383.42	63.90 *
M.D	3	22.94	7.64
D.T	2	.07	.35
M.D.T	6	26.44	4.4
Error	48	1039.2	21.58
Total	71	5025.5	

Table VIII a

Lateral Extent of Root System in cms.

Time of Sampling	Method of Cultivation				Mean
	c_0	h	c_2	c_1	
t_1 (29th June)	52.25	56.25	47.5	55.75	52.93
t_2 (13th July)	59	64	47	57.75	56.93
t_3 (2nd August)	68.75	80.75	78.75	74.75	75.75
Mean	60	67	57.75	62.75	

$\pm$ .948

$\pm$ 1.0932

M.T $\pm$ 1.894

Table IX

MAXIMUM DEPTH OF ROOT SYSTEM

Analysis of Variance

Due to	d.f	S.S.	M.S.S.	
Total	71	3987		
Error	48	864	18	
M.	3	240.55	80.18	**
D.	1	72	72	
T.	2	2478.41	1239.20	**
M.D	3	5.67	1.89	
M.T	6	84.7	14.1	
D.T	2	53.25	26.62	
M.D.T	6	188.42	31.4	

Table IX a

Maximum Depth of Root System in cms.

Sampling Time	Method of Cultivation				Mean	
	c_0	h	c_1	c_2		
t_1 (29th June)	45.5	51	50	45.75	48.06	
t_2 (13th July)	54.25	58.25	51.75	49.25	53.37	$\pm$ 1.000
t_3 (2nd August)	64	74.25	69	68	68.81	
Mean	54.58	61.16	56.91	54.33		

$\pm$ .866

Table X

BRANCHING OF PRIMARY ROOTS

Analysis of Variance

Due to	d.f	2nd Excavation		3rd Excavation		4th Excavation	
		S.S	M.S.S.	S.S	M.S.S.	S.s	M.S.S.
Total	23	4.43		6.705		17.2	
M.	3	.091	.030	.633	.211	.2479	.0826
D.	1	.010	.010	.166	.166	.0337	.0337
M.D	3	.355	.118	1.878	.626	2.193	.7004
Error	16	3.974	.210	4.028	.251	14.7254	.9200

Table Xa

Mean of Branching of Primary Roots

(Number of roots coming out of 1 cm. of primary root)

	Method of Cultivation				
	c_0	h	c_1	c_2	
29th June (2nd excavation)	5.3	5.4	5.4	5.5	± .3911
13th July (3rd ")	5.9	6.1	6.1	6.1	± .6465
2nd August (4th ")	5.2	5.3	5.6	5.4	± .3911

Table XI

DRY MATTER OF LEAVES, STEMS AND LEAVES + STEMS

(Analysis of Variance)

due to	d.f	Plant Portion					
		Leaves		Stems		Foliage (stems + leaves)	
		S.S	M.S.S.	S.S	M.S.S	S.S	M.S.S
M - Method	3	6362.50	2120.83 **	4600.84	1533.61 **	21718.76	7239.5 **
D - Depth	1	15.00	15.00	11.27	11.27	62.26	62.26
T - Time	4	22891.33	5722.85 **	27652.31	6913.07 **	94199.85	23549.9 **
Block	1	50.42	50.42	26.67	26.67	4.08	4.08
M.D	3	332.34	110.78	183.56	61.18	1113.24	371.08
M.T	12	2892.51	241.04 **	2103.35	171.95 **	9141.49	761.7 **
D.T	4	65.93	16.4	40.61	10.15	97.74	24.4
M.D.T	12	1004.73	83.49	545.00	45.4	2489.89	207.48
Error	198	10994.54	55.5	10167.33	51.35	33684.88	170.12
Total	239	44609		45330.94		162522.19	

Table XI a

Weight of Dry Matter of Leaves per Plant in gms.

Sampling Date	Method of Cultivation				Mean	
	c_0	h	c_1	c_2		
t_1 (27th June)	3.5	4.5	4.16	3.91	4.02	
t_2 (12th July)	12.33	19.58	13.75	12.75	14.6	
t_3 (2nd August)	18.33	39.16	23.75	30.5	27.93	± 1.07
t_4 (14th August)	17.91	43.41	29.41	30.75	30.37	
t_5 (6th September)	17.16	33.25	19.91	28.58	24.72	
Mean	13.85	27.98	18.2	21.3		

M.T ± 2.148 ± .961

Table XI b

Weight of Dry Matter of Stems per Plant in gms.

Sampling Date	Method of Cultivation				Mean	
	c_0	h	c_1	c_2		
t_1 (27th June)	1.5	2.91	2.41	2.66	2.37	
t_2 (12th July)	5.66	10.16	6.41	6.41	7.20	
t_3 (2nd August)	9.5	25.33	15.5	19	17.53	± 1.032
t_4 (14th August)	16.5	37.91	26.91	26.91	27.06	
t_5 (6th September)	20.4	38.16	26.9	34	29.86	
Mean	10.71	22.9	15.61	17.83		

M.T ± 2.068 ± .925

Table XI c

Weight of Dry Matter of Foliage Per Plant in gms.

Sampling Date	Method of Cultivation				Mean	
	c_0	h	c_1	c_2		
t_1 (27th June)	5	7.41	6.58	6.58	6.18	
t_2 (12th July)	18	29.83	20.16	19.33	22.02	
t_3 (2nd August)	27.83	64.5	39.25	49.5	45.57	± 1.88
t_4 (14th August)	34.41	81.33	56.33	57.66	57.43	
t_5 (6th September)	37.58	71.44	46.75	62.58	54.58	
Mean	24.53	50.88	33.81	39.13		

M.T ± 3.761 ± 1.683

Table XIII.

Number of Leaves of Potato Plants at Different Times

Analysis of Variance

due to	d.f	26 - 7		13 - 8		23 - 8	
		S.S	M.S.S	S.S	M.S.S	S.S	M.S.S
Total	39	80856.38		81453.98		100740.4	
Plot	19	32472.88		26842.98		36412.4	
M.	4	1848.50	462.12	3148.10	787.25	2828.15	707.37
D.	1	8497.23	8497.23 *	2002.23	2002.23	547.6	547.6
M.D	4	9912.9	2478.22	3111.15	777.78	5686.15	1421.53
Error (a)	10	12214.25	1221.42	18581.50	1858.15	27350.5	2735.0
Sub-plot		48383.50		54611.00		64328.0	
Hand	1	13359.03	13359.03 **	20205.03	20205.03 **	21529.6	21529.6 **
M.H	4	15598.60	3899.65	14997.62	3749.40 *	34041.65	8510.41 **
D.H	1	2235.02	2235.02	1890.62	1890.62	40.	40.
M.D.H	4	5729.60	1432.4	7813.73	1953.43	5496.85	1374.21 *
Error (b)	10	11461.25	1146.12	9704.00	970.40	3219.9	321.9

Table XIII a

Number of Leaves per Plant
at the Second Count.

	h_0	h_1
i_1	71.4	74
i_2	69.2	77

I.H $\pm$ 2.2

Table XIII b

Number of Leaves per Plant
at the Second Count.

	h_o	h_1
w_1	69.4	74
w_2	71.2	77

W.H $\pm$ 2.2

Table XIII c

Number of Leaves per Plant
at the Second Count

$c_o h_o$	58.6	
$c_o h_1$	82.2	$\pm$ 3.1

Table XIII d

Number of Leaves per Plant
23rd August, 1951

h_0	64.6	
h_1	73.8	$\pm$ 1.11

Table XIII e

Number of Leaves per Plant
on 23rd August, 1951

$c_0 h_0$	46.4	$\pm$ 2.52
$c_0 h_1$	83.8	

Table XIII f

Number of Leaves per Plant
on 23rd August, 1951.

	h_0	h_1
w_1	68.2	71.2
w_2	67.6	71.2

W.H ± 1.79

Table XIII g

Number of Leaves per Plant
on 23rd August, 1951

	h_0	h_1
i_1	66.4	71
i_2	69.4	71.4

I.H ± 1.79

Table XIV

Moisture per cent. of Potato Tubers of the Main Experiment at Harvest Time

Analysis of Variance

due to	d.f	S.S	M.S.S.
Total	79	22.97	
Plot	39	11.99	
Block	3	.22	.07
M.	4	.67	.16
D.	1	.26	.26
M.D	4	.79	.19
Error (a)	27	10.05	.37
Sub-plot	40	10.98	
H.	1	.72	.72
M.H	4	.70	.17
D.H	1	.13	.13
M.D.H	4	1.86	.46
Error (b)	30	7.57	.25

The mean moisture percentage of potato tubers of the whole experiment is 74.7 and the dry matter percentage is 25.3.

Table XV

Efficiency Index of Plants

(gm. per gm. per 1 day)

Period	Treatment			
	c_0	h	c_1	c_2
29th June - 17th July	.0871	.1006	.0718	.0851
17th July - 2nd August	.0542	.0610	.0801	.078
2nd August - 14th August	.0548	.0538	.0548	.035

Table XVI a

STORAGE EFFICIENCY
2nd August, 1951

Analysis of Variance

due to	d.f	S.S	M.S.S.
Total	23	521.88	
M.	3	208.17	69.39 *
D.	1	8.41	8.41
M.D	3	12.92	4.3
Error	16	292.38	1202

Table XVI b

STORAGE EFFICIENCY
6th September, 1951

Analysis of Variance

due to	d.f	S.S	M.S.S.
Total	47	154.50	
M.	3	20.50	6.83
D.	1	.4	.4
M.D	3	7.51	2.50
Block	1	.4	.4
Error	39	125.69	3.22

Table XVI c

STORAGE EFFICIENCY OF PLANTS
on 2nd August, 1951

$$\frac{\text{Tuber dry weight}}{\text{Total plant weight}} \times 100$$

	c_0	h	c_1	c_2
d_1	53.3	44	49	42.6
d_2	54.6	43	55	43

Table XVII a

ASSIMILATING EFFICIENCY
2nd August, 1951

$$\frac{\text{Leaves dry weight}}{\text{Total plant dry weight}} \times 100$$

Analysis of Variance

due to	d.f	S.S	M.S.S.
Total	23	230.14	-
M.	3	59.71	19.9
D.	1	1.7	1.7
M.D	3	12.28	4.9
Error	16	156.45	9.77

Table XVII b

ASSIMILATING EFFICIENCY
6th September, 1951

Analysis of Variance

due to	d.f	S.S	M.S.S.
Total	47	158.87	
M.	3	11.95	3.98
D.	1	.48	.48
M.D	3	.91	.30
Block	1	6.98	6.98
Error	39	138.53	3.55

Table XVII c

ASSIMILATING EFFICIENCY UNDER DIFFERENT CULTURAL TREATMENTS

$$\frac{\text{Leaf dry weight per plant}}{\text{Total plant dry weight}} \times 100$$

	c_0	h	c_1	c_2
2 - 8	28.7	32.7	28.1	33.6
6 - 9	3.1	3.7	3	3.6

Table XVIII

YIELD

Analysis of Variance

due to	d.f	S.S	M.S.S.	
Total	79	84249.55		
Plot	39	21579.55		
Error (a)	27	12468.2	416.78	
M.	4	5280.55	1320.13	*
D.	1	480.20	480.2	
M.D	4	1275.55	318.88	
Block	3	2075.05	691.68	
Error (b)	30	3190.25	106.34	
H.	1	46368.45	46368.45	**
M.H	4	10409.05	2602.23	**
D.H	1	156.80	156.8	
M.D.H	4	2545.45	636.36	**

Table XVIII a

Calculation of Error with Complete Randomisation

	due to	d.f	S.S	M.S.S.
	Blocks	3	2,075.05	691.68
	Whole plots	36	15,004.08	416.78
Remainder	Sub-plots	40	4,253.60	106.34
	Total within blocks	76	19,257.68	253.39

Decrease in accuracy on whole plots = 60.806%

Increase " " " sub-plots = 238.28%

Table XVIII b

YIELD WEIGHT IN TONS PER ACRE

(Uncultivated treatments are included)

h_0 12.324

h_1 15.567

$\pm$ .1095

Table XVIII c

YIELD WEIGHT IN TONS PER ACRE

Hand Weeding	Intensity of Cultivation	
	two times (i_1)	three times (i_2)
h_0	12.055	13.563
h_1	15.186	15.624
Mean	13.620	14.593

$\pm$ .1718

I.H $\pm$ .1730

Table XVIII d

YIELD WEIGHT IN TONS PER ACRE

Hand Weeding	Width of Cultivation		Mean
	w_2	w_1	
h_0	12.378	13.240	12.809
h_1	15.813	15.085	15.449
Mean	14.095	14.162	

$\pm$ .1095

$\pm$ .1718

W.H $\pm$ .1718

Table XVIII e

YIELD WEIGHT IN TONS PER ACRE

Width of Cultivation	Intensity of Cultivation		Mean
	two times	three times	
w_1	13.540	14.570	14.05
w_2	13.708	14.627	14.16
Mean	13.62	14.59	

$\pm$ .1718

$\pm$ .1718

W.I $\pm$ .2429

Table XVIII *f*

YIELD IN TONS PER ACRE

Uncultivated hand-weeded treatment	16.203	± .1353
Cultivated hand-weeded treatment	15.408	

Table XVIII *g*

YIELD WEIGHT IN TONS PER ACRE

Uncultivated hand-weeded treatment	16.203	± .3006
Narrow cultivated hand-weeded treatment	15.725	

Table XIX

SEED PER CENT.

Analysis of Variance

due to	d.f	Seed per cent M.S.S.	Ware per cent M.S.S.
Error (a)	27	16.02	18.86
Method	4	17.51	23.72
Depth	1	13.07	50.68
Block	3	14.85	40.19
M.D	4	8.96	3.20
Sub-plot	40		
Error (b)	30	4.59	2.77
Hand-weeding	1	21.61 *	48.98 **
M.H	4	31.49 **	26.06 **
D.H	1	2.32	.39
M.D.H	4	22.54 **	12.04 **

Table XIX a

Calculation of Error
with Complete Randomisation

(Seed per cent.)

due to	d.f	S.S	M.S.S.
Block	3	44.57	14.85
Whole plots	36	576.72	16.02
Sub-plots	40	183.6	4.59
Total	76	760.32	10.004

Table XX a

WARE PERCENTAGE

	c_0		c_1		c_2		c_3		c_4	
	D_1	D_2	D_1	D_2	d_1	d_2	d_1	d_2	d_1	d_2
h_0	31.7	29.5	33.5	31	39.7	35.5	39.5	38	40.5	36.2
h_1	41.2	35	36	40.5	39.2	36.2	42	37	36	35.7

Table XX b

SEED PERCENTAGE

	c_0		c_1		c_2		c_3		c_4	
	d_1	d_2	d_1	d_2	d_1	d_2	d_1	d_2	d_1	d_2
h_0	65.7	64	63.2	65.7	52.5	60.2	57.2	56.7	58	60.5
h	56	61	61	54	59.2	61.2	53.7	61	59.5	59

Table XXI

GERMINATION RATE INDEX

Analysis of Variance

due to	d.f	M.S.S.
Total	15	
Depth of planting	1	.027811 **
Block	3	.000911
Error	11	.000386

Table XXII

Per cent. of plants came-up by stated dates

Planting depth	20th May	22nd	24th	26th	28th	30th	1st June	3rd	5th	7th June
d_1 deep	10.7	21.7	39.6	65.3	72.2	80.9	86.4	91.5	96	100
d_2 shallow	18.9	34.4	55.5	76.5	81.8	87.7	93.1	97.5	98.5	100

Table XXIII

Per cent. of Came-Up at Different Periods

Planting depth	20-22 May	22-24	24-26	26-28	28-30	30th May-1st June	1 - 3	3 - 5	5 - 7 June
d_1 deep	11.0	17.9	25.7	6.9	8.7	5.5	5.1	4.5	4
d_2 shallow	15.5	21.1	21.0	5.3	5.9	5.4	4.4	1.0	1.5

Table XXIV

FLOWERING RATE INDEX

Analysis of Variance

due to	d.f	M.S.S.
Total	15	
Block	3	.00083756
Planting depth	1	.01025156 **
Time of weeding	1	.00043056
D.T	1	.00000057
Error	9	.00083217

Table XXIV a

Per cent. of Plants Flowered by Stated Dates

Date	9th July	11th	13th	15th	17th	19th July
Deep planting	.4	8.5	39.1	58.5	91.4	100
Shallow planting	.8	13.6	45.8	68.9	95.3	100

Table XXIV b

Per cent. of Flowering at Different Periods

Period	9th-11th July	11-13	13-15	15-17	17-19
Deep planting	8.1	30.6	19.4	32.9	8.6
Shallow planting	12.8	32.2	23.1	26.4	4.7

Table XXV

NUMBER OF LEAVES PER PLANT
Analysis of Variance

due to	d.f.	12th June M.S.S.	24th June M.S.S.	30th June M.S.S.	9th July M.S.S.	21st July M.S.S.
Total	15					
Error	9	7.30	26.84	47.2	68.67	93.25
D - Depth of planting	1	49.7 *	94.09	324 *	959.45 **	1463.06 **
T - Time of weeding	1	1.0	21.62	43.5	3.9	70.56
D.T	1	.32	.06	3.48	43.23	1.44
Block	3	10.56	61.01	27.18	195.66	274.53

Table XXV

HEIGHT OF PLANTS

Analysis of Variance

due to	d.f	M.S.S. 30th June 1952	M.S.S. 10th July 1952	M.S.S. 21st July 1952
Total	15			
Block	3	22.26	116.33	100.02
D - Depth	1	8.7	60.45	15.01
T - Time of weeding	1	36.6	66.83	116.10
D.T	1	.36	4.52	2.33
Error	9	15.82	66.66	121.54

Table XXVI

TOTAL YIELD, WARE PER CENT. AND SEED PER CENT.

Analysis of Variance

due to	d.f	Total yield M.S.S.	Ware per cent. M.S.S.	Seed per cent. M.S.S.
Total	15			
Block	3	96.91	2.00	2.02
Depth of planting	1	656.25	4.2	2.17
Time of weeding	1	240.25	5.52	3.51
D.T	1	104.00	.18	.04
Error	9	189	1.6	1.71

Table XXVII

TOTAL YIELD, WARE PER CENT., SEED PER CENT., CHAT PER CENT. Under Different Treatments.

	Treatment			
	Deep planting (d_1)		Shallow planting (d_2)	
	t_1	t_2	t_1	t_2
Total yield tons/acre	16.8	15.9	18.0	17.3
Ware %	84	85.7	83	84.2
Seed %	14	12.7	14.7	13.7
Chat %	.2	1.6	2.3	2.1

Table XXVIII

NUMBER OF LEAVES PER PLANT

Analysis of Variance

due to	d.f	S.S.	M.S.S.
Total	71	20935.01	
Block	5	293.02	58.60
Treatment	2	2305.32	1152 66 **
Time	3	15991.90	5330.63 **
Treatment x Time	6	930.80	155.13 **
Error	55	1413.97	25.63

Table XXVIIIa

Number of Leaves per Plant

Date of Counting	W	h	P	Mean
16th June t_1	23.8	30.8	26	26.8
1st July t_2	39.5	52.3	39	43.6
14th July t_3	51.4	71.4	54.1	58.9
28th July t_4	55	70	71.3	65.4
Mean	42.4	56.1	47.6	

$\pm$ 1.191

$\pm$ 1.029

Treatment x Time Interaction $\pm$ 1.679

Table XXIX

DRY WEIGHT OF LEAVES

Analysis of Variance

due to	d.f	S.S.	M.S.S.	
Total	71	10165.99		
Block	5	69.47	13.89	
Treatment	2	866.37	433.18	**
Time	3	7623.62	2541.20	**
Treatment x Time	6	410.56	68.42	**
Error	55	1195.97	21.74	

Table XXIX a

DRY WEIGHT OF LEAVES PER PLANT
in gms.

Date of Sampling		W	h	P	Mean
16th June	t_1	10.1	11.9	9.9	10.6
1st July	t_2	23.2	30.4	21.0	24.8
14th July	t_3	27.2	42.7	34.5	34.8
28th July	t_4	31.5	40.3	37.8	36.5
Mean		23.0	31.3	25.8	

$\pm$ 1.104

$\pm$ .948

Treatment x Time interaction $\pm$ 1.902

Table XXXI

STEMS DRY WEIGHT

Analysis of Variance

due to	d.f	S.S	M.S.S.
Total	71	8499.3	
Block	5	159.45	31.89
Treatment	2	194.63	97.31 *
Time	3	6707.2	223.50 **
Treatment x Time	6	167.45	27.90
Error	55	1272.57	23.13

Table XXXI a

STEM DRY WEIGHT OF A PLANT
in gms.

Date of Sampling		W	h	P	Mean
16th June	t_1	2.33	2.98	2.38	2.56
1st July	t_2	11.81	12.60	11.35	11.92
14th July	t_3	19.50	28.83	23.50	23.94
28th July	t_4	23.50	28.83	27.50	26.61
Mean		14.28	18.31	16.18	

$\pm$ 1.131

$\pm$ .980

Table XXXII

TUBER DRY WEIGHT

Analysis of Variance

due to	d.f	S.S	M.S.S.
Total	53	87404.39	
Block	5	306.82	61.3
Treatment	2	3825.74	1912.87 **
Time	2	70045.21	35022.60 **
Treatment x Time	4	1960.71	490.17
Error	40	11265.92	281.648

Table XXXII

MEAN TUBER DRY WEIGHT PER PLANT

(a) At Different Times

1st July 73.6 gm.

14th July 315.2 " ± 3.954

28th July 602.3

(b) Under Different Treatments

Unweeded treatment 276.3 gm.

Pruned Root " 317.0 " ± 3.954

Hand-weeded " 397.8 "

Table XXXIII

TUBER DRY MATTER PER CENT.

Analysis of Variance

due to	d.f	S.S	M.S.S.
Total	71	245.83	
Block	5	6.75	1.35
Treatment	2	8.37	4.18 *
Time	3	165.96	55.32 **
Treatment x Time	6	2.7	.45
Error	55	62.05	1.12

Table XXXIII a

TUBER DRY MATTER PER CENT.

Date of Sampling	W	h	P	Mean
1st July t_1	15.91	15	15.91	15.60
14th July t_2	16.63	15.65	15.6	15.96
28th July t_3	20.66	19.5	18.73	19.63
20th August t_4	20.66	19.5	19.66	19.94
Mean	18.46	17.41	17.47	

Table XXXIV

NUMBER OF TUBERS PER PLANT

Analysis of Variance

due to	d.f	S.S	M.S.S.
Total	71	510.56	
Block	5	20.66	4.13
Treatment	2	196.65	98.32 **
Time	3	12.12	4.04
Treatment x Time	6	27.79	4.63
Error	55	253.34	4.60

Table XXXIV a

NUMBER OF TUBERS PER PLANT

Date of Sampling	W	P	h	Mean
1st July t_1	12.7	14.4	10.6	12.56
14th July t_2	10.7	15.1	11.9	12.56
28th July t_3	10.9	14.8	11.4	12.36
August t_4	9.6	14	10.8	11.46
Mean	10.97	14.5	11.17	

$\pm$ .504

$\pm$ .437

Table XXXV

SOIL MOISTURE

Analysis of Variance

due to	d.f	S.S	M.S.S.	
Total	17	60.11		
Block	5	2.53	.506	
Treatment	2	35.36	17.68	**
Error	10	22.22	2.22	

Table XXXv a

SOIL MOISTURE

% of Different Treatment

Unweeded treatment	10%
Hand-weeded "	13.8%
Pruned-root "	13.3%

Table XXXVI

LATERAL EXTENT OF ROOT SYSTEM

Analysis of Variance

due to	d.f	S.S	M.S.S.
Total	53	2096.11	
Block	5	25.44	5.08
Time	2	788.52	389.26 **
Treatment	2	734.24	371.12 **
Treatment x Time	4	392.03	98.00 **
Error	40	165.88	4.147

Table XXXVI a

LATERAL EXTENT OF ROOT SYSTEM OF POTATO PLANT in cms.

Date of Sampling	W	h	P	Mean	
16th June t_1	30.65	36.20	28.56	31.80	
1st July t_2	36.51	42.25	26.80	35.18	± .479
14th July t_3	40.33	43.33	39.33	40.99	
Mean	35.83	40.59	31.56		

± .479

Treatment x Time Interaction ± .831

Table XXXVII

MAXIMUM DEPTH OF ROOT SYSTEM

Analysis of Variance

due to	d.f	S.S	M.S.S.
Total	53	1191.55	
Block	5	35.53	7.10
Treatment	2	292.93	126.46 **
Time	2	553.65	276.82 **
Treatment x Time	4	140.43	35.10 **
Error	40	209.01	5.22

Table XXXVII a

MAXIMUM DEPTH OF ROOT SYSTEM OF POTATO PLANT
in cms.

Date of Sampling	W	h	P	Mean	
16th June t_1	33.9	34.6	32.0	33.5	
1st July t_2	36.8	40.0	32.0	36.2	± .538
14th July t_3	40.1	44.5	39.1	41.2	
Mean	36.9	39.7	34.3		

± .538

Treatment x Time Interaction ± .932

Table XXXVIII

BRANCHING OF PRIMARY ROOTS

Analysis of Variance

due to	d.f	S.S	M.S.S.
Total	53	84.38	
Block	5	20.00	4.00
Time	2	.4	.2
Treatment	2	4.61	2.30
Time x Treatment	4	.14	.035
Error	40	59.23	1.48

Table XXXVIII a

BRANCHING OF PRIMARY ROOTS

Number of Roots Coming Out of 1 cm. of Primary Root

Date of Sampling	W	h	P	Mean
16th June t_1	8.43	7.71	8.20	8.11
1st July t_2	7.77	8.56	7.58	7.97
14th July t_3	8.15	8.11	8.08	8.11
Mean	8.11	8.12	7.95	

$\pm$ .0901

$\pm$ .0901

Treatment x Time Interaction $\pm$ .4959

Table XXXIX

RELATIVE GROWTH RATE PER WEEK

Analysis of Variance

due to	d.f	S.S	M.S.S.
Total	53	1.23960006	
Block	5	.00832746	.00166549
Treatment	2	.01344693	.00672346
Time	2	.58146304	.29073152 **
Treatment x Time	4	.25331912	.06332978 **
Error	40	.38304349	.00957608

Table XXXIX a

RELATIVE GROWTH RATE PER WEEK

(gm. per gm. per 7 days)

Period of Sampling	W	h	P	Mean	
16th June - 1st July t_1	.5083	.5154	.2946	.4394	
1st July - 14th July t_2	.3071	.4080	.4586	.3912	± .023
14th July - 28th July t_3	.1999	.1704	.2273	.1992	
Mean	.3384	.3646	.3268		
		± .023			

Treatment x Time Interaction ± .0398

Table XL

RELATIVE LEAF GROWTH RATE PER WEEK

Analysis of Variance

due to	d.f	S.S	M.S.S.
Total	35	.68828391	
Block	5	.00897102	.00179420
Treatment	2	.02562162	.01281081
Time	1	.38904327	.38904327 **
Treatment x Time	2	.06769270	.03384635 *
Error	25	.19695530	.00787821

Table XL a

RELATIVE LEAF GROWTH RATE

(gm. per gm. per 7 days)

Period of Sampling	W	h	P	Mean
16th June - 1st July t_1	.3843	.4375	.3506	.3908
1st July - 14th July t_2	.1141	.1692	.2653	.1828
Mean	.2492	.3033	.3079	

$\pm$ .0209

Treatment x Time Interaction $\pm$ .0362

Table XLI

NET ASSIMILATION RATE

Analysis of Variance

due to	d.f	S.S	M.S.S.
Total	35	4.927992	
Block	5	.486086	.097217
Treatment	2	.615516	.307758
Time	1	.190969	.190969
Treatment x Time	2	.257982	.128991
Error	25	3.377439	.135097

Table XLI a

NET ASSIMILATION RATE

(gm. per gm. per 7 days)

Period of Sampling	W	h	P	Mean
16th June - 1st July t_1	.797	.971	.844	.870
1st July - 14th July t_2	.723	1.143	1.142	1.002
Mean	.760	1.057	.993	

$\pm$ .0866

$\pm$ .105

Treatment x Time Interaction $\pm$ .15

Table XLII

THE RELATIVE PROPORTIONS OF PLANT PARTS THROUGHOUT THE LIFE CYCLE

		$\frac{\text{Root + Stolons Dry Weight}}{\text{Total Plant Weight}} \times 100$			$\frac{\text{Foliage Dry Weight}}{\text{Total Dry Weight of a Plant}} \times 100$			$\frac{\text{Tuber Dry Weight}}{\text{Total Dry Weight of a Plant}} \times 100$		
		W	h	P	W	h	P	W	h	P
t_1	16th June	27.8	28	34.6	72	71.1	65.1	00	00	00
t_2	1st July	4.4	4.5	6.0	69.3	69.5	74.8	26.1	25.3	19.3
t_3	14th July	2.4	2.0	2.6	48	40.3	55.6	46.6	46,1	47
t_4	28th July	1.3	1.1	1.5	36	37.5	44.6	62.3	63	59

Table XLIII

TOTAL YIELD AND WARE PERCENTAGE

Analysis of Variance

Due to	d.f	Total Yield		Ware %	
		S.S.	M.S.S.	S.S.	M.S.S.
Total	55	8277.36		360.43	
Plot	27	2023.36		200.45	
Method of cultivation - M	6	634.61	105.76	98.9	11.483
Replication	3	123.14	41.04	25.39	8.46
Error (a)	18	265.61	103.64	106.16	5.89
Sub-plot	28	6254		159.98	
Hand-weeding - H	1	3031.14	3031.14 **	70.88	70.88 **
M.H	6	1179.11	196.51	20.88	3.48
Error (b)	21	2043.75	97.32	68.22	3.248

METEREOLOGICAL OBSERVATIONS

Station: Boghall County: Midlothian

Lat.: 55° 52' N. Long.: 3° 12' W.

Height above mean sea level: 639 feet.

Dry Mains Farm is approximately four miles from Boghall.

1951

The months of March, April and May were mild but the temperature was always below the average of the last ten years. The rainfall was excessive in all the three months. The planting of potatoes was delayed by about three weeks. The total rainfall during the last week of April was about 7.5 inches which is very high.

In the month of June rainfall was well below the average and the first week was completely rainless.

The sunshine was generally abundant except in March.

1952

As the metereological data for 1952 has not been fully compiled, the figures for that year are not given in the table. The general remarks about rainfall, temperature and sunshine are:-

The rainfall was more or less the same as the last ten years' average with the exception of the first fortnight in April. The planting was done on 22nd April. There was heavy rainfall during the month of June. Bright sunshine was above the average amount and so was the temperature.

Month	TEMPERATURE (F.)		RAINFALL (Inches)		SUNSHINE (Hours)	
	1941-50 Mean	1951	1941-50 Mean	1951	1941-50 Mean	1951
January	35.63	35.80	3.02	3.90	39.55	58.60
February	36.79	34.70	2.45	2.40	71.12	70.70
March	40.45	36.10	2.09	3.40	101.01	77.80
April	45.14	41.60	2.27	4.30	138.36	150.60
May	48.44	46.20	2.87	6.10	166.04	166.70
June	55.00	54.20	2.17	1.80	170.82	192.70
July	57.88	57.90	2.91	3.90	146.71	158.30
August	57.08	55.70	3.99	5.60	131.26	121.80
September	53.68	54.80	3.28	1.30	107.81	152.40
October	48.18	48.60	2.91	0.80	86.77	110.50
November	41.69	39.90	3.10	5.10	57.64	94.70
December	38.78	40.70	2.64	3.20	42.73	52.10